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THE SCIENTIFIC MONTHLY

FEBRUARY, 1923

THE MAYENCE BASIN, A CHAPTER OF GEOLOGIC HISTORY

By Professor EDWARD W. BERRY

THE JOHNS HOPKINS UNIVERSITY

GEOGRAPHERS have done well in emphasizing the influence of geography upon human affairs, and the history of strategic regions whether they be river valleys, coastal plains or other lanes of attack, or merely paths of migration of races, or overland trade routes—and all three are usually the same—is one of the most fascinating of subjects. The more primitive the race the more dependent is it upon local environment, and we find the men of the Old Stone Age passing along and settling in those regions in Europe that have since, times without number, been regions of envious neighbors and shifting sovereignty.

No equal area is of more interest to the student of later geologic history than the Mainz basin, or Mayence basin as it is frequently called, for it belonged to France from 1797 to 1814. One would suppose that it was a sharply defined geographic unit, such as Steinheim, for example, but it has no especially well-marked natural boundaries on all sides, neither is it a political entity; nevertheless the name is well chosen.

The Rhein valley, from where it turns to the northward out of the Jura mountains at Basel, winds northward in a wide valley some thirty miles in width, and maintains this direction for a distance of about 225 miles. Then it turns sharply to the west and, after flowing along the southern flank of the Slate Mountains, it turns again northward at Bingen into the justly celebrated Rhein gorge.

The juxtaposition of lowland and upland are features here brought about by breaks and slips in the earth's crust, and the plain of the Rhein from Basel to Frankfurt is one of the best known as well as the most perfect example of a sunken earth seg-

ment (graben) bounded on either side by fault scarps. The strata of the Vosges Mountains on the west side dip to the westward, and they are exactly duplicated in the Black Forest on the east side, where they dip in the opposite direction, and a tyro can see that here are the remains of a great crustal arch or anticline with a slice about 30 miles in width missing from the crest of the arch.

The city of Mainz itself is picturesquely situated on rising ground on the left bank of the Rhein, just where the westerly flowing Main joins that stream. It is one of the oldest cities in Germany, and its site was recognized as a strategic point by the Celts, who had a settlement here. The Romans under Drusus, Augustus' son-in-law, built a fortified camp here about 13 B. C., and this became finally the capital of *Germania Superior*, and in consequence grew in size and importance, with the result that it was repeatedly razed by Alamanni, Vandal and Hun. Many relics of the Roman period escaped total destruction and still gladden the tourist. The Chatti, who inhabited the vicinity in Roman times, are perpetuated in the name Chattian, which Fuchs proposed in 1894 to designate the uppermost stage of the Oligocene, since the rocks of this age are so well developed and abundantly fossiliferous in Hesse.

The town of Mainz thrived during the long reign of Charlemagne and became a free city in 1118. It is not to be wondered at that it is still strongly Catholic, for it was the see of an archbishopric as early as the eighth century, and the tomb of Boniface, the first archbishop, is still to be seen in the rather notable Romanesque cathedral dating from the tenth century, along with the tombs of Frauenlob, the Minnesinger, and many of the electors, for the archbishopric was one of the seven electorates of the Holy Roman Empire. In the thirteenth century Mainz was the center and main support of the league of Rhenish towns, but the illiberal rule of the archbishops and the military struggles between rival claimants resulted in a gradual decline of the city during the fifteenth century, although it was here in 1450 that Johann Gutenberg set up his first printing press.

Although ideally located for commerce, this has always been hampered by its strategic position from a military point of view, so that it has been greatly distanced by its easterly neighbor, Frankfurt. No place is more redolent with historical associations than Mainz, although Strasburg, 150 miles up the valley, perhaps rivals it in modern interest.

The Rhein plain is nowhere over 650 feet in elevation, and from Spires on down to Bingen it is only half this height. The Mainz basin may be considered as an inverted triangular area with its

base formed by the fault bounding the southern margin of the Taunus, and marked by the town of Wiesbaden. The eastern limb may be considered as formed by the highland masses of the Vogelsberg, Spessart and Odenwald, the last a northward continuation of the Black Forest (Schwarzwald), from which it is separated by the river Neckar. The western limb, with its base resting on the Hunsrück, is formed by the Hardt, a declining northward continuation of the Vosges Mountains, which rises, however, in the Donnersberg, west of Worms, to 2,254 feet. The apex of the triangle may be placed at Spires. There is no clear demarcation between the Mainz basin and the upper Rhein plain, and similarly to the northeast the low country with characteristic Tertiary geology continues between the Taunus and the Vogelsberg to the river Lahn at Giessen. This latter region is the brown coal area known as the Wetterau and celebrated for its fossil plants and lignite.

The bounding uplands rise rather abruptly from the basin, being largely determined by faults, and are attractive vineyard covered rural districts, for grape raising supports the main industry of wine making, for which the region is famous. For our knowledge of the geology of the basin, we are principally indebted to a long succession of German geologists and paleontologists who have diligently studied the deposits and fossils of this classic region,

FIG. 1. GEOGRAPHY OF THE MIDDLE OLEGOCENE. WHITE = LAND, LINED = SEA.

many of whom have been aided by the scientific society and museum at Frankfurt.

The geological history of the Mainz basin as an individual unit, as distinct from its history as a part of a larger geological province, begins in the Oligocene Tertiary with the depression of the middle Rhein valley between the Vosges-Taunus and the Black Forest-Odenwald regions of older rocks. This depression brought about the first flooding of the Mainz basin, as such, by the Oligocene sea, which at that time was advancing over the old land surface of Europe. In this area this old land surface which forms the basement rocks of the Mainz Tertiary sediments consisted of middle and upper Permian (Rothliegende) with its quartz porphyry and melaphyr igneous intrusions, of hard Devonian shales or slates, of the Rhein schists of the Odenwald or of old basaltic sheets.

At that time the geography of Europe was very different from what it is at the present time, much of the central and southern part of the continent being submerged, as may be seen in Figure 1.

An enlarged Spanish peninsula was united with an abbreviated France to form a large Western Island, from which a southeasterly peninsula included most of Corsica and Sardinia. This island was separated by narrow seaways from the enlarged British Isles on the north and from Africa on the south. On the west rolled the Atlantic, but on the east the Western Island was separated from the sausage-shaped island marking the present site of the Alps by a narrow strait, and a similar strait separated it from the long sigmoid peninsula that extended all of the way from Iran and Asia Minor through the Balkan, Carpathian and Bohemian massifs to the Black Forest region of southern Germany. The site of the future Caucasus mountains was also an island, a great sea extending eastward from the North sea, covering north Germany, all of southern Russia and northern Armenia. Most of Italy was submerged, the Oligocene Mediterranean sweeping over Italy and the lands bordering the east Adriatic as far as Thrace.

The Mainz basin at this time was an irregular strait connecting the North German sea with the Mediterranean, narrowest just north of Frankfurt, where it was only about 15 miles across and rather shallow. According to Haug the marine fauna found in these initial deposits of the Mainz basin—the Meeressand—is so like that found in the sands of Fontainebleau in the Paris basin that there must have been a direct sea connection between the two by way of the Saar and Lorraine regions, but there is no corroborative evidence for such a geographic pattern. Tidal or other currents were sufficiently active in this region at the beginning of our history to prevent the accumulation of sediments finer than sands,

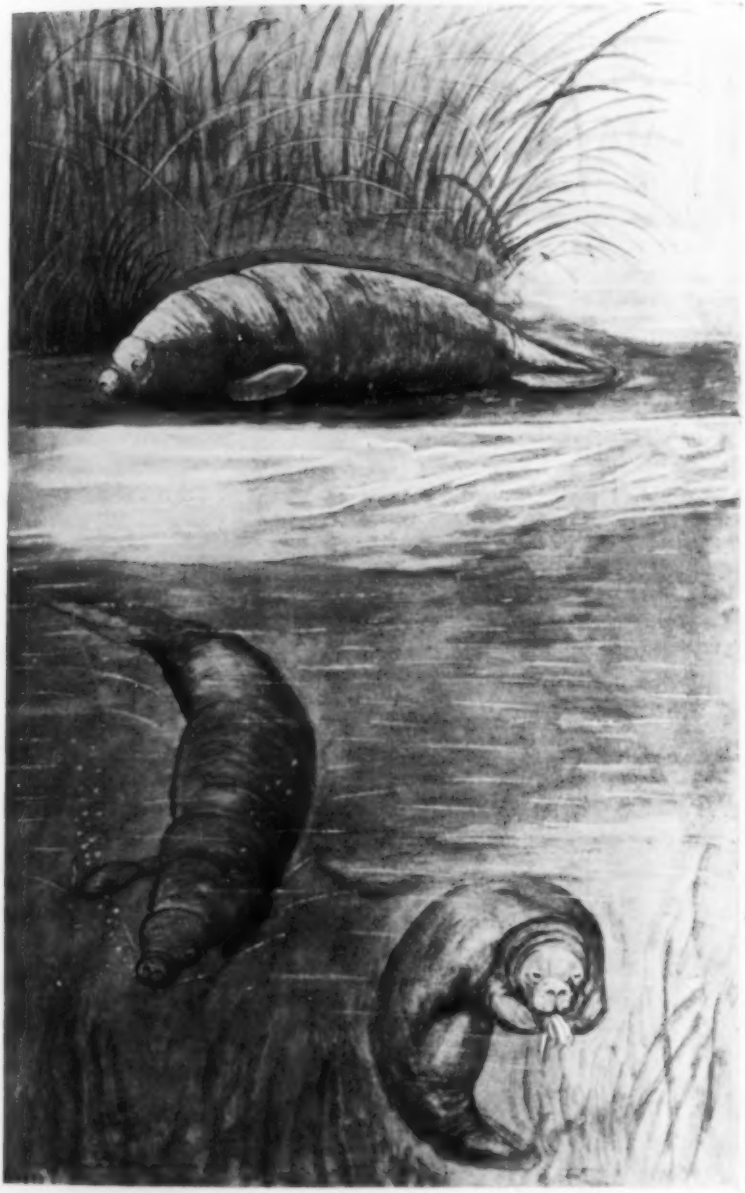


FIG. 2. RESTORATION OF THE MAINZ MANATEE HALITHERIUM SCHINZI KAUP ABOUT 1/37 NATURAL SIZE

and erosion was active at this time on the bordering lands, for the old shores are lined with conglomeratic beds.

These initial deposits of the Mainz basin constitute the Meeressand of German geology. They are essentially the littoral and shore sands of the transgressing sea—older in the middle part of the basin and progressively younger in passing outward to its borders, being gradually replaced in the deeper and quieter parts of the basin by first sandy muds and then more pure muds (clays). The fauna that has been found in the Meeressand is very extensive and almost entirely marine in character. Among the mammals are a sea cow (Halitherium) and seal (Phoca), and a hornless rhinoceros (Aceratherium) whose grave happened to have been the sea floor instead of its native forests. There are traces of four reptiles, including two turtles; and four fishes, all of which were sharks. A barnacle and some 30 different ostracod crustaceans have been recognized. Molluscs were numerous and varied (59 gastropods including a land snail, 2 scaphopods, 2 chitons and 55 pelecypods). There were 3 brachiopods, 6 bryozoa, 2 sea urchins, 10 corals and about 100 foraminifera.

The most striking denizen of the Mainz waters was the Oligocene sea cow or manatee (Halitherium) whose bones are so common in the Meeressand and the partially overlying Rupel clay. A restoration of this animal is shown in Figure 2, where for the sake of clearness one individual is shown lying on the shore, although these animals never left the water in life. During Eocene times, many thousand years earlier, in the then humid region of Nubia, the Ungulate ancestors of the manatee and dugong forsook the competition of the terrestrial environment and gradually became adapted for an exclusive aquatic mode of life, eventually entirely losing their hind limbs, although these are still retained in the Libyan Eosiren, having the fore limbs modified to form flippers, developing a horizontally flattened fluke on their hind ends to facilitate their vertical movement in the water and having the bones become extraordinarily heavy to aid them in remaining submerged while browsing on the aquatic vegetation of the shallow waters.

These animals constitute the order Sirenia, so named from the quaint conception of the early naturalists that the existing forms were sirens or mermaids. Ancestral forms were probably common along the shores of the Mediterranean lands of both hemispheres during the Tertiary, continuing in Europe as late as Pliocene times when they are found as far north as Belgium. The Mainz manatee, *Halitherium schinzi* Kaup, shown in the accompanying illustration, was a slow inactive vegetarian of the estuaries, which, like its mod-

ern representatives, was probably gregarious in its habits and never ventured far from the shallow waters where its food was abundant.

All but two of the dozen known genera of sea cows are extinct. These occur only in the warm, mainly tropical regions, although rhytina, the northern sea cow of Behring Sea, survived in that region until exterminated by man in the eighteenth century. The existing sirenians comprise three oriental species of Dugong ranging along the coasts from East Africa to eastern Australia, and three species of Manatee found from southern Florida to Brazil and on the west coast of Africa between latitudes 16° North and 10° South. The most striking difference between the manatee and the dugong is in the tusks with which the male dugong is armed. The latter is also more of a sea margin type and tidal feeder, whereas the manatee is more of a river form, the African species occurring inland to Lake Tchad, and the Amazon species ranging to the head waters of the great system and present in abundance in the summer flooded lands at the foot of the Andes. The present and past distribution of the sirenians is shown in the accompanying sketch map, Figure 3.

With the progress of time the sediments known as the Meeressand passed gradually both seaward and upward into more muddy materials, the Rupelthon or Septaria clay, so-called because there was enough calcium carbonate in the deposits to bring about the formation of the jointed concretions known as septaria, and which

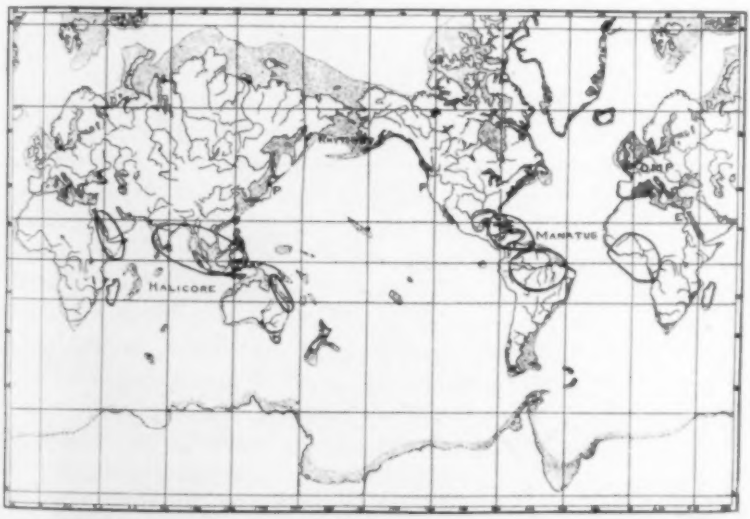


FIG 3. GEOLOGIC AND GEOGRAPHIC DISTRIBUTION OF THE SIRENIA. E—EOCENE, O—OLIGOCENE, P—PLIOCENE

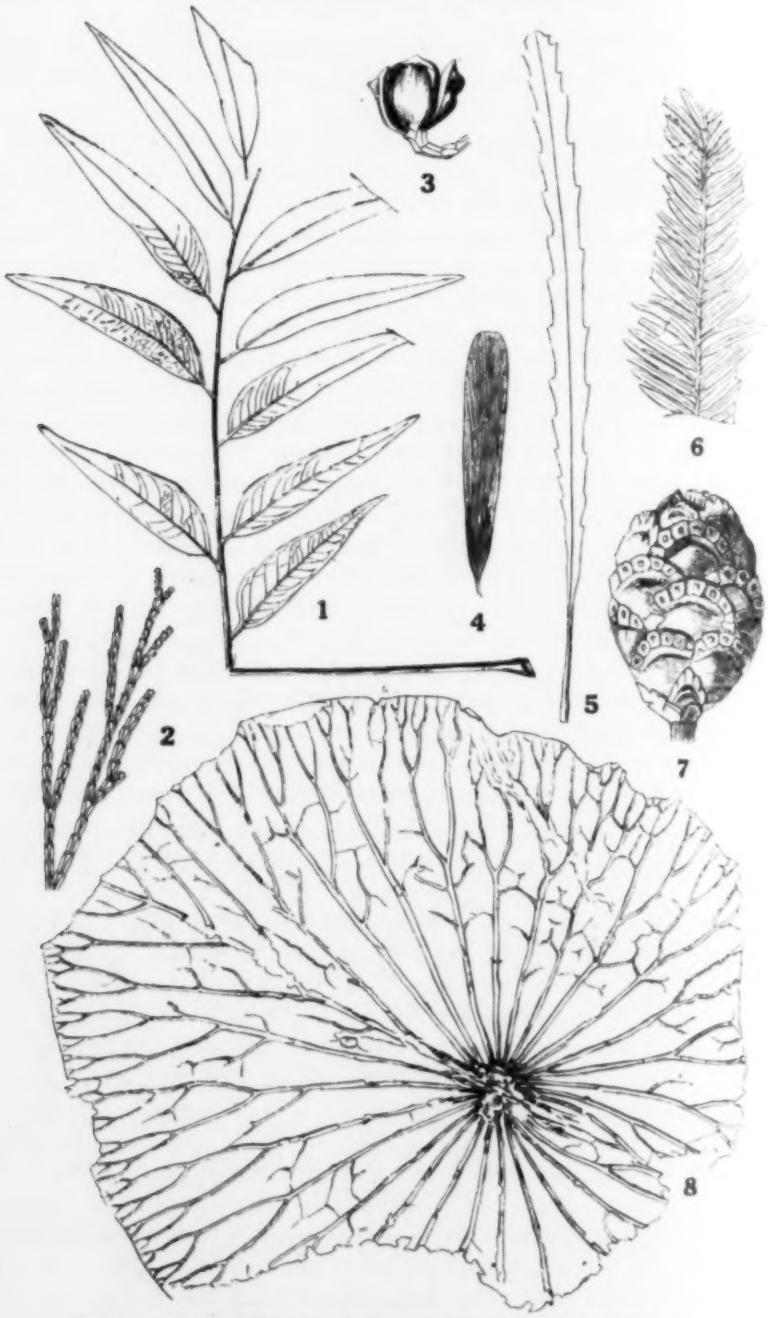


FIG. 4. SOME RUPELIAN PLANTS OF THE MAYENCE BASIN

1. *Sapindus falcifolius*, X ½. 2. *Callitris brongniarti*, twig. 3. Cone. 4. *Fraxinus primigenia*, fruit. 5. *Banksia longifolia*. 6. *Taxodium dubium*, twig. 7. Cone. 8. *Nelumbium buchi*, X ½.

are a prominent feature of these clays. They are almost always more or less sandy and accumulated in the central part of the Mainz basin to a thickness of over 350 feet. They are capable of a rough three fold separation, the lower transition beds being sparsely fossiliferous.

The discovered fauna includes the sea cow, a turtle, some 36 fishes including rays and many sharks, such as to-day are represented in coastal waters of warm climates. There were two crabs and 17 ostracod crustaceans, a starfish and 79 foraminifera. Molluscs were fairly abundant (19 gastropods, 1 scaphopod, 15 pelecypods) and included three of those small pelagic type known as sea butterflies (Pteropoda). At this horizon there have also been discovered 72 different plants that grew on the surrounding shores. Among these were palms, incense cedars, representatives of our American sequoias and bald cypress, pines, bayberry, figs, laurels, sassafras, cinnamon, ash, soapberry and myrtle; many representatives of warm climate genera such as Pisonia, Echitonium, Myrsine, Bumelia, Bombax, Terminalia Eugenia, Myrcia, etc. Some of these are shown in Figure 4.

As the sediments of the Meeressand graded imperceptibly into those of the Septaria clay, so those of the latter passed gradually into those known as the upper Meeressand, or Schleichsand, as it is commonly called. This last is a fine-grained micaceous sand with a considerable admixture of silt and reaches a maximum thickness of about 160 feet. Its fauna is similar to that of the Meeressand, but is less abundant and varied. It consists of a reptile, a shark, a barnacle and 8 ostracods, 24 marine and brackish gastropods and 14 land and fresh water gastropods, 39 bivalves, mostly muddy bottom types, a sea urchin and 17 foraminifera. Thirty-five species of plants, essentially similar to those of the Septaria clay, mark the contributions from the forested shores. From a larger viewpoint the Meeressand, Septaria clay and Schleichsand, which constitute the Rupelian stage of the Oligocene, can be considered as essentially a sandy unit beginning with the sands of the transgressing sea, with a middle period of offshore muds and reduced run-off from the land, and a late interval of agitated waters as the basin shallowed and the run-off from the bordering lands increased.

A shallowing or filling of parts of the basin results in the appearance of sediments representing brackish and fresh water which follow those of the Rupelian. These are the Cyrenia marl, essentially calcareous muds with some buried swamp deposits, the Melania clay, a mud deposit largely developed in the Rhön region northeast of the basin beyond the Frankfurt straits. This progressive shallowing, which first becomes apparent in late Rupelian

times continues throughout the deposition of the Cyrenia marl in the basin, eventually resulted in emergence, and this emergence is marked in places by the remains of stream gravels and sands, and fresh water limestones containing fossil land snails. The fossils of the Cyrenia marls comprise representatives of 9 mammals including four different rhinoceroses, 4 fishes, 20 crustaceans, 21 bivalves, 21 marine and brackish and 16 land and fresh water gastropods, 1 sea moss, 11 foraminifera and 2 aquatic plants, including Chara.

The snail limestone, of local occurrence around the northern and western borders of the basin, is found in disconnected small patches, and from these very many fresh water and land shells have been described. The old northwestern bay south of Bingen and southwest of the site of Mainz was entirely occupied by fresh waters at this time in which were deposited the fresh water marls (calcareous clays). The more central portions of the basin, in all probability cut off from direct communication with the open sea, was filled by water rendered brackish by the influx of fresh water from the streams which flowed into it. According to the current interpretation of the Germans, these Cyrenia marls, lignitic clays, fluvial gravels, sands and fresh water limestones constitute the Chattian or closing stage of the Oligocene. French paleontologists, with probably greater justification, consider the Chattian stage to include the three succeeding divisions to be described presently, and which the Germans refer to as the lower Miocene or Aquitanian stage.

Overlying the brackish or fresh water sediments just mentioned there occur a series of limestones, marls and sands that indicate a slight deepening of the basin with a temporary renewal of the connection with the Mediterranean. This deepening resulted in a recession of the shores so that the marine sediments of the first or Cerithium stage transgressed the continental deposits of the preceding stage. At this time a shallow gulf about 30 miles in width extends northward beyond Mainz and Frankfurt, becoming sandy at its head north of the latter place. The fauna of the Cerithium stage is limited, comprising 9 species of mammals whose carcasses washed into the bay from the surrounding lands; a barnacle and 4 ostracod crustaceans; 19 gastropods, largely estuarine types and characterized by several species and varieties of the genus Potamides which is the basis for calling these deposits the Cerithium beds; 11 mostly estuarine bivalves and 4 foraminifera.

The Cerithium beds were followed by the Corbicula beds, so-called from the abundance in them of the species *Corbicula faujasi*. The time of deposition of the Corbicula beds is marked by a general

elevation or a northward tilting of the region, which gradually cut off the connection with the Mediterranean at the south and widened the basin of sedimentation northward in the Wetterau and Vogelsberg regions southeast of Giessen, and in this more northern area were laid down sands and clays including the leaf sandstone of Münzenberg, so-called from the abundance of the leaves of land plants which it contains. The depauperate fauna comprises 8 mammals, 2 reptiles, 1 fish—a perch, 10 ostracods, a caddis fly larva, 32 gastropods, mostly brackish and fresh water forms, 4 brackish or fresh water bivalves and 3 foraminifera. The fossil plants comprise about 33 species and include palms, bald cypress, alder, beech, elm, fig, willow, cinnamon, maple, buckthorn and walnut. This flora appears to lack most of the warmer climatic types that characterized the earlier Oligocene of this region and hints at a slight climatic change.

The continued change of level progressively restricted the area of sedimentation, which now, during the time occupied in the deposition of the Hydrobia beds became a lake, which was about 135 miles in length from north to south and about 50 miles wide at its widest part which was at about its middle from what is to-day Bingen on the west to Darmstadt on the east. Only a few relics of the former marine faunas of the basin, like the muscle (Mytilus) and a couple of foraminifera in the earliest layers, survived and became buried in the sediments of the Hydrobia lake. These lake beds do contain, however, a considerable representation of the contemporary mammal fauna of the surrounding lands. These amount to 37 different species and include opossum, both horned and hornless rhinoceroses, the tapir, squirrel, musk-rat, mole, shrew, bats, primitive pigs, bear-like dogs, primitive deer, mustelines, etc. There have also been found in these beds the remains of 2 herons, 11 reptiles, mostly turtles, 4 amphibians, 4 fishes, 9 ostracods, 1 caddis fly larva, 54 fresh water gastropods and two bivalves, as well as occasional leaves of land plants and Chara fruits. In the Rhön region lying to the eastward of the northern bay of the Hydrobia lake extensive beds of clay with swamp deposits (brown coal) were being formed during the time the lake was silting up and disappearing. These lignitic clays contain considerable floras, that from Wieseck near Giessen being probably of this age. The lignitic clays of Elm, characterized by extinct mammals known as Anthracotheres and belonging to the genus Brachyodus is also of this age, or it may be slightly younger, some authors referring it to the Burdigalian stage of the Miocene.

A very long period of emergence and erosion followed the close of the last Oligocene deposits—the Hydrobia beds, probably con-

comitant with and caused by the same influences which were bringing about the initial uplifts in the region of the Alps. This interval of emergence and erosion and lack of sediments, in accordance with the interpretation presented here, lasted throughout the Aquitanian, Burdigalian and Helvetian stages of the Miocene or about half way through that epoch. The oldest true Miocene of the Mainz basin consists of continental beds now found only in its eastern part. In the western and southern parts of the basin Miocene sediments of any kind appear to be entirely absent.

This oldest Miocene is known as the land snail marl and it is represented in the region from Darmstadt northeastward. These beds correspond to the Sylvana beds found elsewhere in Germany, and are of Tortonian age. They contain patches or stocks of algal limestone, and have yielded a fauna which is very limited aside from the numerous species of land and freshwater snails. There are several small land mammals and birds preserved in these deposits, as well as a land tortoise and a tree toad. The fishes include a species of Lepidosteus of the ancient and waning race of gar pikes. Two fresh water ostracods and the remains of a water lily (Brasenia) also occur at this horizon. Vulcanism is a prominent feature of the history of the region from this time onward for several thousand years, the lava flows from the Vogelsberg dating from this time.

Immediately succeeding the land snail marls are another series of marls especially characterized by the presence of the gastropod shells known as *Melania escheri* and *Melanopsis marzolina*, and usually considered to be of late Miocene or Sarmatian age. These were followed in the Frankfurt region by muds and swamps which formed the lignitic clays characterized by the gastropod genus Prososthenia and often called the Prososthenia beds. The limited fauna found in these beds includes a frog, 2 fishes, 6 gastropods and 14 insects. The fossil plants found at Salzhausen in the Wetterau are considered to be of this age, but may be older. The flora that is known to have flourished at this time numbers about 50 species and includes a fan palm, coniferous trees representing the genera Glyptostrobus, Sequoia, Libocedrus, Widdringtonia, Taxodium and Pinus—only the last being present in the flora of modern Europe. This abundance of coniferous trees indicates somewhat dryer soil conditions and a more temperate climate, and this influence is borne out by the deciduous trees represented, which include birch, alder, oak, beech, hazel, elm, plane tree, willow, pistacia, maple, buckthorn and grape. This is a quite modern assemblage, and the invasion of the region by the grape is to be especially noted. The following represent types of trees which were constitu-

ents of the Mainz forests at that time, but which subsequently disappeared from the continent of Europe—sweet gum, fig, persimmon, soapberry, walnut and hickory.

Following the Prososthenia beds were continental sands and stream gravels which are widely spread in Germany and quite generally known as the Dinotherium sands. They were contemporaneous with the clays containing the bivalved mollusc, *Congeria kayseri*, and are referred to the Pontian or latest Miocene stage. The last basaltic sheets of the Wetterau and the Rhön were contemporaneous with these sands and clays. These Dinotherium sands contain the relics of a highly interesting mammal fauna—the so-called Eppelsheim fauna found near the historic town of Worms.

This fauna includes an ape—a true gibbon (Pliohylobates)—a beaver, two elephants—the large *Tetralophodon longirostris* and the giant dinothere, *Dinotherium giganteum*. Six carnivors have been found, including two sabre toothed tigers, a wolf-like dog, a hyena of the same species as lived in the grottos of Pentelican marble in Attica (Pikermi). There were two hornless rhinoceroses and a large Dicerorhinus of the Sumatran type, a horse and a tapir, four different pigs and five species of deer. The last are especially interesting since in the Pikermi fauna of Greece which is the same age or very slightly younger than this Manz basin fauna, the deer of the latter are replaced by a variety of antelopes, denoting a more open plains country which has been eloquently pictured by Gaudry. The Mainz deer include a musk deer (Hyaemoschus), a hornless deer (Palaeomeryx), a true deer (Elaphus), and two cervulines or muntjacs (Dicrocerus). The Mainz country of this time was obviously more heavily wooded and swampy than Greece or the emerged Aegean plain, which were land at that time.

The Dinotheriums are supposed to have entered Europe from Africa during the lower Miocene at a time when southern Europe was a region of low forests comparable with the existing forested country of East Africa. They are very imperfectly known but apparently lived on in Europe through Miocene times. Two species are known from the lower Manchhar beds (Sind) of India, and the genus survived in the later Miocene of the Punjab—forms related to the Mainz *Dinotherium giganteum* having been reported from the older Siwalik beds of the Punjab (India). The Dinotheriums constitute a sub-order or super-family of the elephant phylum, and were largely fluviatile or semi-amphibious in their habits—perhaps the term palustrine describes their habits more adequately, since they were essentially denizens of swampy areas. The Mainz species was the giant of the race and because it is so imperfectly known it seemed desirable to attempt its portrayal, although it should be

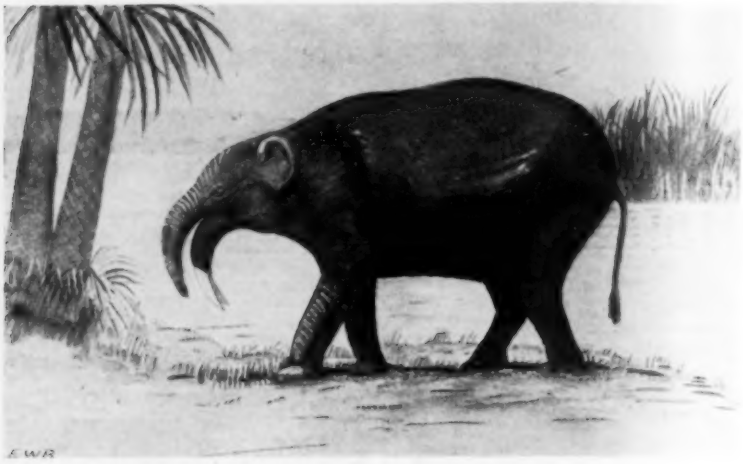


FIG. 5. RESTORATION OF DINOTHERIUM GIGANTEUM KAUP, ABOUT 1/55 NAT. SIZE

borne in mind that nothing approaching a complete skeleton is available for such a restoration. (See Figure 5.)

The contemporaneous flora is less fully represented by fossils in the Mainz basin than at synchronous localities in France, Italy and Austria. From Laubenheim near Mainz the paleobotanist Goeppert identified the following plants, which, however, give us a very imperfect picture of the actual botanical composition of the forests and swamps of that time: *Quercus furcinervis, cuspidata* and *undulans, Fagus deukalionis* and *castaneaefolia, Liquidambar europaeum, Laurophyllum crassifolium, Echitonium sophiae, Bumelia oreadum, Aralites lanceus* and *Dombeyopsis lobata*. Except for the oaks and beeches these all belong to genera no longer found in the European flora.

Following the deposition of the Dinotherium sands, the geological record of the Mainz basin is a blank in so far as sedimentary beds are concerned, although a basalt sheet dates from this time, until upper Pliocene times. These upper Pliocene deposits are stream, lake and flood plain sediments—sands, clays and lignites (brown coal). Their contained relics of the life of the times include a few fresh water shells and the remains of an extensive flora. This flora consisted of many pines, larch, spruce, fir, sequoia, bald cypress, incense cedar, callitris, ginkgo, birches, poplars, beech, hazel, walnut, hickory, elm, sweet gum, many grapes, hackberry, maple, water lilies, box, buckthorn, holly, sumach, etc.

It is of exceedingly great interest because of the number of elements which it contains representing the Holarctic north temperate flora, and which at the present time have long been entirely

extinct in the European area. Among the striking examples of what happened to this Holaretic flora in Europe during the Pleistocene glaciation are walnut and hickory whose fruits are like those of existing North American forms; bald cypress, indistinguishable from our American tree; Callitris—now north African; Torreya—now American and Asiatic; Cephalotaxus and Ginkgo, both now eastern Asiatic; and other equally striking cases which might be mentioned. Some of these plants are shown in Figure 6.

Then came the Pleistocene Ice Age, which, during its four periods of glaciation worked havoc with the noble races of Holaretic animals and plants that formerly inhabited Europe. In the Mainz

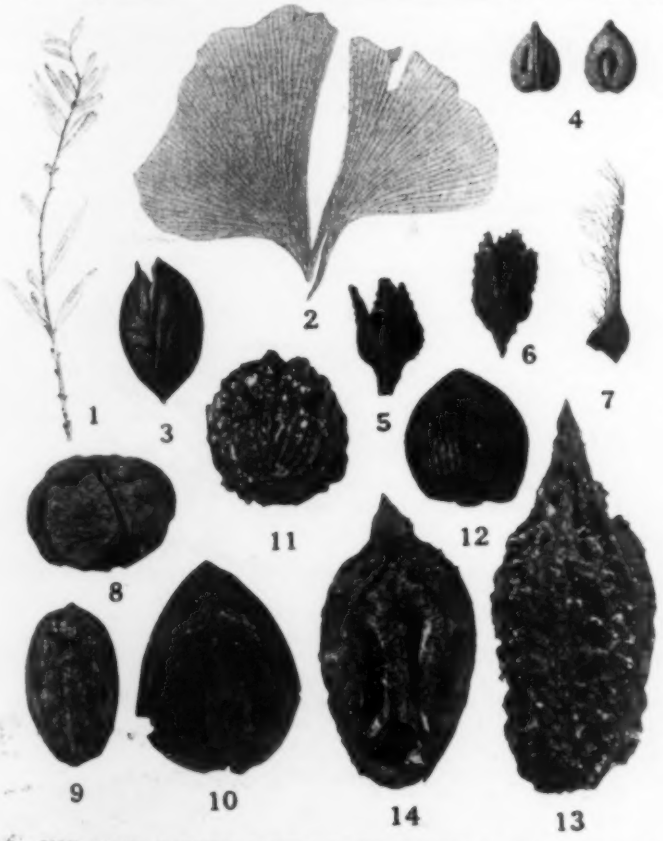


FIG. 6. SOME UPPER PLIOCENE PLANTS OF THE MAINZ BASIN, NATURAL SIZE.

1. *Taxodium dubium* Sternberg, twig. 2. *Ginkgo adiantoides* Unger, a leaf. 3. A stone of this species. 4. *Vitis sphærocarpa* Kinkelin, seeds. 5, 6. Burs of the beech, *Fagus pliocenica angustilobata*. 7. Key of a maple, Acer. 8. Hickory nut, *Hicoria ovata* Miller *fossilis*. 9. Nut of *Hicoria olivæformis*. 10. Half of nut of *Hicoria sattleri*. 11. Nut of *Juglans nigra fossilis*. 12. Nut of *Corylus avellana fossilis*, the hazel. 13. Butternut, *Juglans cinerea fossilis*. 14. Half of a butternut.

basin the Pleistocene deposits are sands, gravels and loams, with the fine-grained wind-blown material known as loess. From the great Scandinavian center of accumulation the continental ice sheet spread southward, crossing the lower Rhein and reaching beyond the site of Berlin, but failing to reach the Mainz region by about 150 miles. The Alps, which at the close of the Tertiary had attained their modern proportions, were also the scene of extensive glaciation, sending out their glaciers into the surrounding lowlands, but these reached only as far as the upper Rhein valley a long distance above Mainz, so that the Mainz basin itself remained

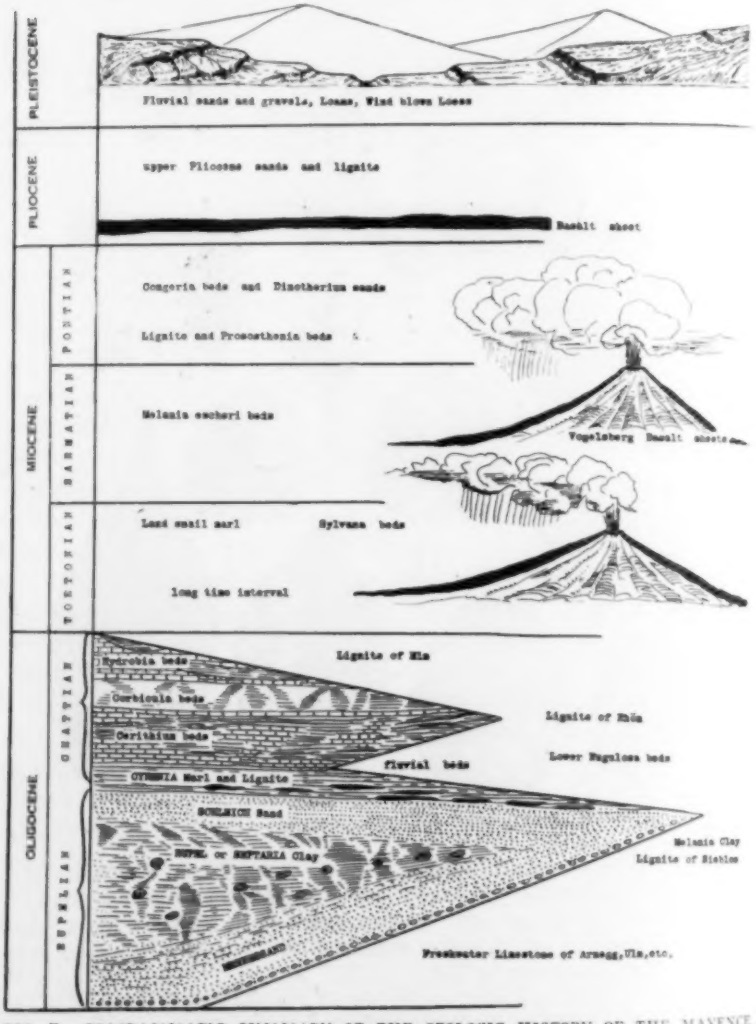


FIG. 7. DIAGRAMMATIC SUMMARY OF THE GEOLOGIC HISTORY OF THE MAYENCE BASIN

unglaciated. It shared the general history of Europe, with the extreme fluctuations of glacial and interglacial periods, which resulted in the extermination of so many forms of life. It was during the Pleistocene, too, that the men of the Old Stone Age arrived in western Europe, but in these later times the Mainz basin loses the identity which attaches to it from Oligocene to Pliocene times, and its later history is henceforward a part of the general geologic history of Europe and need not prolong our discussion.

I have attempted a diagrammatic summary of the history of the Mainz basin in the accompanying illustration constituting Figure 7, and which I hope is self explanatory.

LICHENS—IMPOSSIBLE PLANTS

By ALBERT W. C. T. HERRE

THE PHILIPPINE BUREAU OF SCIENCE

AMONG the most singular and inexplicable of organisms are those known to botanists as lichens. Common folks lump them together as "moss" along with liverworts and the true mosses, if indeed they observe them at all. But as a rule they are unnoticed, though we may find scattered through the works of poets and novelists many references to lichens. For example, Praed wrote

> O'er the natural tomb
> The lichened pine rears up its form of gloom,

While Bridges saw

> The red roofs nestle, oversprent
> With lichen yellow as gold.

Whitman, hunting for wild flowers, says

> Here oft we sought the violet, as it lay
> Buried in beds of moss and lichens gray,

but Erasmus Darwin with uplifted eyes looked to

> Where frowning Snowden bends his dizzy brow
> Retiring lichen climbs the topmost stone.

The finest description and most vivid picture of lichens limned by poets is perhaps that of prolific old J. G. Herder, who nearly a hundred and twenty-five years ago wrote these lines:

> Wer hat je de Flechten, wer hat die Moose gezählet,
> Deren Frühling beginnt, wen Fröste den Herbst entblättern,
> Deren üppiger Wuchs die Scheitel ätherischer Alpen
> Da, wo sie Flora verlässt, mit tausend Farben bekleidet?

Of a different stamp are the many references which do not distinguish them from the mosses, as in the familiar introduction to Longfellow's "Evangeline,"

> This is the forest primeval. The murmuring pines and the hemlocks,
> Bearded with moss and gray,

or Mrs. Hemans's "red cup-moss."

A lichen is not an organism or species in the same sense that we use the word in referring to other plants or animals. A coconut crab or the tree on whose fruit it feeds, an apple tree or an

ant crawling along its trunk, each is a distinct species, a definite entity of more or less homogeneous structure with organs and tissues of a common primary origin and a definite common specific heredity. Each of the examples cited is the product of the union of a sperm and an egg cell from like parents and can come into being in no other way. It is true that some animals and many plants propagate wholly or in part parthogenetically, that is, without the fertilization of the egg, and that others increase in numbers through some form of somatic or cell division. But no matter what the exact method, it is impossible to have a coconut crab whose parents were anything but coconut crabs, or to get a cross between a fern and a flowering plant, a liverwort and a moss, a shark and a sardine, a bat and a bird.

Yet when we examine lichens we find an entirely different state of affairs. A lichen is composed of two entirely unlike organisms, belonging to two entirely distinct and altogether different groups of plants. Biologically a lichen is therefore composed of and is the resultant of the interaction of two distinct and utterly unlike living organisms which go to make up its body, and in consequence is what we may term for lack of a better distinction a physiological and not a morphological species.

If we section a lichen and examine its anatomy we find it to be made up of a fungus and an alga. The form and texture of most lichens is due to the fungus, its hyphæ or filaments often being compacted at the surface to form a thick strong cortex, while from the lower surface they extend as rhizoids or otherwise simulate roots. The alga on the other hand is nearly always distributed in a layer within the body of the lichen but much nearer the upper or outer surface, so that in section it forms a streak of bright green enmeshed in the white threads of the fungus. In the gelatinous lichens, such as the *Collemaceae* and the *Ephebaceae* and a few other families, the shape or habit of growth of the lichen is due to the algal element, the fungus making up but a small part of the lichen.

A more careful microscopic examination of the structure of a lichen shows that the algal cells are not only surrounded by fungal hyphæ, but that the latter are closely appressed against the algæ or even send haustoria into the algal cells, in either case drawing from them by osmosis elaborated foods and often destroying them.

In ordinary fungi the vegetative part is usually reduced in size since it obtains its food already prepared, as when it lives as a saprophyte, or takes food from the host as it is manufactured, in the case of parasites. The fungus of a lichen, however, has the

new duty of enveloping and protecting the alga so that the latter may increase in number and perform more effectively the task of manufacturing food for the fungus. A result of this is perhaps the reason for the development of the greatly varied and complex bodies of the higher lichens. The fungus supplies the alga with water and mineral salts and may also carry more or less of its carbon supply to it. The alga is protected in such a way that it is able to grow where it would be impossible to do so alone and its continued existence, through cell division, is assured, though fission goes on slowly as a rule, while reproduction by zoospores is entirely inhibited. It is self evident that the algal host cells, usually remote from the surface of the lichen, are in a much less favorable position for carrying on photosynthesis than when they are free. Sooner or later they are killed by parasitism or parasitism and saprophytism together.

It is this strange association of two unlike organisms, a fungus as master living as a parasite or a saprophyte upon an enslaved alga, which gives rise to the anomalous organisms called lichens, plants which differ markedly from either of their components.

The older botanists regarded lichens as one of the primary divisions of plants, a class equal in rank to any other. There was constant speculation over the origin of the green cells or gonidia as they were called, as they are so unlike the rest of the thallus. Lichenologists finally accepted the idea that they were formed from the colorless hyphæ and it was not until 1867, when Schwendener announced his "dual hypothesis," as it was dubbed, that the real nature of lichens began to be understood. His discoveries were bitterly denounced by systematic lichenologists who could not bear to see their favorites deprived of their important rank. Careful experiments with both constituents and with the spores produced by the fungal portion have at last established beyond question the truth of Schwendener's discoveries as to the twofold nature of lichens. Most botanists have accepted the theory that the association of alga and fungus is one of symbiosis or mutual helpfulness, and this is the view ordinarily presented in botanical texts. Here in the Philippines, as well as elsewhere in the tropics, we have remarkable and mutually beneficial associations between certain plants and ants, and in all parts of the world different kinds of animals or plants and animals dwell in relationships involving more or less mutual service. To merely list these would require a large amount of space, and many instances of more or less perfect symbiosis will be found in any elementary text. But the writer fails to find parallel cases among the lichens and agrees with Bruce Fink that morphologically "a lichen is a fungus, usually.

if not always, more or less parasitic during all or part of its life upon an algal host and also sustains a relation to an organic or inorganic substratum."

It therefore follows automatically that lichens should not be treated as a separate class but should be redistributed among the fungi by the systematist, thus doing away altogether with the class lichens. It is not at all likely that this will be done very soon as there are many difficulties in the way. Reproduction among lichens is peculiar; we are too ignorant of the fungal relationships of many lichens; while the interaction of alga and fungus has resulted in an organism and a mode of life which differ markedly from that of fungi, so that as a matter of convenience it is far easier to group lichens together than to have them scattered here and there among the fungi. These are some of the reasons why many botanists insist that lichens constitute a distinct class of fungi, if not indeed two.

Nearly all the fungi occurring in lichens belong to the *Ascomycetes*, though there are a few tropical species belonging to the *Basidiomycetes*. In most cases these fungi no longer live independently, that is, outside the lichen association and away from the algæ with which they have developed, though some live for years in their substrata without the algæ and become parasitic upon them later. The fungal constituent of most common lichens has been evolved from either the *Discomycetes* or the *Pyrenomycetes*. Such genera as *Peziza*, *Patellaria*, *Melaspilea*, *Phacidium*, *Chaetomium*, *Sordaria*, *Hysterium* and *Thelophora* are among those apparently closely related to the ancestors of the lichen fungi.

The algæ are of many kinds, though the great majority belong to a few families of green algæ or *Chlorophyceæ*, mainly to the *Protococcaceæ* and *Trentepohliaceæ;* there are also a few species belonging to the *Mycoideaceæ*, *Prasiolaceæ*, and *Cladophoraceæ*, occurring in lichens. The algal constituents of all gelatinous as well as many non-gelatinous lichens belong to the *Myxophyceæ* or blue-green algæ. They include various species of the *Chroococcaceæ*, *Nostocaceæ*, *Rivulariaceæ*, *Stigonemaceæ* and *Scytonemaceæ*.

Most of the algæ are readily recognizable as common, widespread species, but some of them, especially the blue-green forms, are often greatly modified so as to be unrecognizable by one who has only observed them under free living conditions. About one per cent. of the species of blue-green algæ are known to occur in lichens, the proportion of green algæ being very much smaller.

The fungal portion of ordinary lichens produces the characteristic fruiting body of the Discomycetes or Pyrenomycetes. The lichen fruit is known as an apothecium and of course has no connection

with and bears no relation to the algæ within the lichen. Some lichens are not known in a fruiting condition, while in a great many others the fruit is either usually or else always imperfect or sterile, the asci or thecæ never developing or forming spores. But many lichens do produce fertile spores which in time are thrown out to be distributed by the wind. Those alighting in favorable places readily germinate and in time may develop into lichens like the one from which they came, the hyphæ enveloping the proper kind of algæ from those growing on the substratum.

However, it is doubtful if the majority of lichens ever grow from spores even though they produce viable ones, but they propagate in an entirely different way. Upon the surface of the thallus of most lichens more or less minute powdery separable particles called soredia are formed, making up an amorphous powdery excrescence or a pustular body termed a soralium. Each individual soredium is composed of one or more algal cells characteristic of the particular lichens, entwined in lichen hyphæ or fungal threads. Each soredium is therefore a microscopic bit of lichen thallus and is a form of vegetative reproduction characteristic of these strange plants.

As the soredia are set free they become widely distributed by the wind and soon make their appearance on all suitable exposed substrata where they develop into the characteristic form of the particular species from which they came.

While propagation by soredia may be compared to ordinary vegetative reproduction by bulblets, gemmæ, budding, the breaking off of pieces of a mother plant or animal and other natural means, as well as by means of cuttings, it is only analogous and not homologous. Soredia are unique in that each minute speck or soredium includes two dissimilar organisms.

It is not at all surprising that this comparatively recent method which absolutely ensures the continuation of the composite life should have so largely superseded the uncertain method inherited from the fungal ancestor, since the latter leaves too much to chance.

Discussion of the development and structure of the apothecia, of sexual reproduction in a few lichens, of cephalodia, and the numerous structures and adaptations peculiar to lichens is here omitted.

At what period lichens originated we know not, for authentic records of fossil lichens earlier than the Cenozoic are doubtful, though it is possible that they existed in Mesozoic time.

Lichens did not have a single ancestor, but originated independently with numerous representatives of the two great groups

of fungi already named, and as previously stated these became associated with many different algæ belonging to two entirely different classes and several different orders. The evidence for the polyphyletic origin of lichens is beyond question, but though they have no common origin their manner of life is in all cases practically the same and they have therefore altered profoundly from the fungi from which they sprang. Their long life as compared to the ancestral fungi, their ability to persist through great climatic changes, their ability to endure successfully long periods of suspended activity and the formation of lichen acids which are not found in any other plants and are an excretion of the fungus, all serve to mark them as a distinct group.

There are some puzzling things about heredity in lichens. There is no inheritance in the sense in which that term is used in speaking of ordinary plants and animals. Not only do most lichens lack any form of sexual reproduction, but the spores produced can not transmit any lichen characters since they are produced by only one component of these weird plants. No chromosomes transmit the specific peculiarities of any given lichen, and the student of Mendelian inheritance can not point to anything comparable to the classic discoveries in sweet peas, guinea pigs, fruit flies, man and other organisms whose heritable characteristics are juggled about in the chromosomes of their germ cells. Yet lichens are among the most variable of organisms in spite of or perhaps because of their lack of germ plasm. Certainly here is a fertile field for the proponent of the inheritance of acquired characters to cultivate, using argument as his tool, as if argument ever settled anything, or for the students of eugenics by careful experiment to determine as nearly as possible just how lichens transmit heredity.

Although lichens are so variable, the same species, though with a multiplicity of varieties and forms, may occur over vast areas. But these changes, undoubtedly due to variations in light, heat, moisture and substrata, instead of ranging visibly about a fixed mean act differently in regions of geographic isolation. Here, apparently through control by a kind of orthogenesis or orthoselection, their variation goes on unimpeded in a given line until new species are produced. These new species may have become fixed or they may still be highly unstable and in process of splitting into two species having different habitats, *i. e.*, different substrata, as I have previously shown elsewhere. One great group of lichens, the *Cladonias*, is still in process of evolution as was long ago shown by Wainio, the great authority on this puzzling group, though it is perhaps no more variable than some well-known groups of flowering plants. About 40,000 species of lichens have been described, of which perhaps 15,000 may be called valid.

By the early systematists lichens were divided into three artificial groups according to their habit of growth. Crustaceous lichens are sufficiently defined by the name and pass by easy stages from the most inconspicuous forms up to the foliaceous or leafy lichens, or by another line into the fruticose, which may be erect and shrub-like or thread-like and pendulous. It follows then that a lichen may be of almost any shape, regular or irregular, which could be imagined in plants varying through such extremes as insignificant, barely visible dark stains and specks upon rocks or half buried in bark, or a group of minute pits in limestone, up to conspicuous leafy or bushy forms a foot or two across, great tangled masses of black hair, or enormous pendent gray growths reaching several yards in length.

Their color may vary from pure white to dead black, or brown, intense red, or bright yellow, but the commonest is a soft neutral sea green or gray green which lacks the vivid hue of ordinary green leaves. The color may be due to the algal constituent, as in the gelatinous lichens, to various pigments deposited in the walls of the fungal hyphæ, or to crystals of lichen acids excreted from the hyphæ and lying on the outer walls. A few rock lichens are tinged with iron rust due to iron salts in the substratum or water. Though many lichens are very beautiful, in most regions their colors are not at all conspicuous, but in some places, as in the mountains of the arid parts of the western United States, they often form the most brilliant feature of the landscape. Here one may see great boulders gaily splashed or huge cliffs made gorgeous by vermillion, orange, or vivid yellow crustaceous lichens. The spotted alders and many other trees in various parts of the world owe their characteristic mottled or variegated bark to the innumerable circular patches of pale or white lichens, while in the tropical rain forest great conspicuously colored, gray green, white, brown or even blood red areas of bark are the result of exuberant lichen growth.

One of the advantages of studying lichens is that collections may be made almost anywhere, though it must be admitted that great manufacturing districts are not favorable for their growth. But in general they occur from pole to pole and from sea level to the peaks of the loftiest mountains, wherever there is anything not covered permanently by ice or snow upon which they may alight and develop. On the ground, on rocks of all kinds, on the bark, leaves, exposed roots or dead wood of trees or any perennial plants, we may find them all over the world. One species grows upon the thallus of Polyporus and other bracket fungi, and one species is truly aquatic, growing on submerged rocks in mountain

streams. Many lichens swiftly avail themselves of fences, posts, wharves, barns and other unpainted wooden structures, and again others seem able to grow upon almost anything. One may find them, therefore, upon iron fences and the metal as well as the wooden parts of old farm machinery, on sun-bleached bones, dried dung, brick walls, old shoes, dead shells on the sea strand and even on ancient church windows.

A very few kinds grow upon the thallus of other lichens, but most of the species with this habit which have been described as lichens are really fungi, since they totally lack algæ.

No climate is too wet, too dry, too hot or too cold for lichens of some kind to flourish. The talus blocks of rhyolite exposed to the cloudless glare of the sun in a region with an annual rainfall of no more than 8 inches are covered with drought resistant lichens as closely aggregated as they can crowd, while the desert below sea level and with a rainfall of less than 2 inches has a plenitude of rock and earth lichens which thrive in a heat as great as earth affords. On the other hand the pinnacles of the great Puget Sound volcanoes or the sky-splitting peaks of the Alps are thickly crusted with layers of dark lichens or swathed in leathery, blizzard-defying *Gyrophoras*. From the farthest north land seen by Peary in his trip to the pole a bit of rock was sent me on which the lichens left no unexposed surface, while on many seashores rocks submerged at every tide are equally well covered by these strange plants. The lace lichen, *Ramalina reticulata*, largest and bulkiest of North American lichens, reaches its maximum development with a rainfall of about 16 inches, while in the forests of the outer coast range of Oregon or the mountains of Java, where the rainfall is measured with a yard stick, *Usnea longissima* justifies its name, attaining at times a length of 10 meters.

In the past most botanists and students of ecology have disregarded lichens in their observations, assuming without real investigation that they are worth nothing in this respect, but as a matter of fact they are probably not surpassed by any plants in value as true climatic indicators. From a study of the lichen flora alone of a given region one may learn all the important facts of its climate.

Lichens are, with trifling exceptions, perennial plants and a majority are of relatively slow growth and long life. While some, especially the large foliaceous species of regions with mild, humid climate, grow with great rapidity so that falling leaves and twigs are caught and embedded by their swiftly spreading tissues, others hardly change in appearance during the span of a human life. Many of the common, inconspicuous crustaceous and foliaceous

lichens become established and produce apothecia in from four to eight years, after which they may live for several times that before finally disappearing. As trees grow old and their bark roughens many lichens once conspicuous on them pass away because they are mechanically destroyed by the loss of epidermis and the hyperdevelopment of the cork layer in the bark.

Many lichens, such as the *Cladonias*, keep dying at the base and growing at the top much as the peat-forming *Sphagnum* mosses do, and like them may outlive the forest trees. Some of the crustaceous and foliaceous lichens die at the centre after a time, but continue to grow and spread at the circumference as long as there is any space left unoccupied, decade after decade seeing but little change. Since there is no vital growing point or area in a lichen, injury of one portion leaves the rest undamaged, and there is accordingly no limit to the age of many lichens. On huge open surfaces of rock one may observe vast circular mats or irregular sheets of *Parmelias* or enormous well-defined areas of *Lecanoras*, *Lecideas*, *Rhizocarpons* or other crustaceous genera which may apparently live, barring accident, as long as the cliffs stand.

From the remotest historical periods lichens have been valued and utilized by man. They were used for medicine by the Egyptians more than 3,000 years ago, while Pliny wrote, "As well in this wild kind as in planted plum trees of the hortyard, there is to be found a certain skinny gum, in Greek called Lichen, which hath a wonderful operation to cure the rhagadies or chaps." Down to the last half century a number of them were esteemed as valuable curatives but now only one of them, "Iceland moss," is still recognized by the U. S. Pharmacopoeia.

From the days when the merchants of Tyre carried her noted dyes and other valuable commodities to all the regions known to the inhabitants of the shores of the Mediterranean, down to the present, lichens have furnished many of the most valuable dyes. They were especially prized in northern countries, and it was not until the rise of the aniline dye industry that lichens became of secondary importance to the dyer. To-day they furnish the chief purple dyes for wool and silk and are the source of the valuable chemical color test for acids and alkalies—litmus.

In the frozen regions of Lapland, Siberia, Alaska and the Barren Grounds the chief vegetation over vast areas is *Cladonia rangiferina*, the noted "reindeer moss." This lichen is of the utmost economic importance to the Laplander and all the other peoples eastward to Hudson Bay, since upon it reindeer, caribou, deer and cattle depend for food during the long winter. In northern Sweden the people gather and store it for their cattle. In Iceland the islanders use "Iceland moss" in the same way.

While lichens contain no true starch or cellulose they contain a peculiar carbohydrate known as lichenin, which is an anhydride of galactose. Many lichens contain large amounts of lichenin and would be valuable food for man were it not that they also contain bitter acids which cause digestive trouble when eaten. By boiling or soaking with cooking soda or other weak alkalies so as to largely eliminate or neutralize the acids they may be eaten. "Iceland moss" is the best of these foods, and is used to a considerable extent in Iceland and the remoter districts of Norway and Sweden. Other lichens are used in various parts of the world, a noted one being a *Gyrophora* used in Japan and China since remote times. Another is *Lecanora esculenta*, a desert lichen which is supposed to have been the manna of the Israelites and which is known to the Arabs as "bread from heaven." Its food value, however, is very low.

It is in another capacity altogether that lichens are of the greatest importance, a field from which they will not be driven by advances in chemistry and which they will occupy as long as the existing conditions of life endure. Lichens are the pioneers in breaking down rock surfaces and in preparing the way for higher plants. In the rainy tropics blue-green algæ are the first to make their appearance upon freshly exposed surfaces, but elsewhere lichens are supreme in this difficult and extremely important rôle.

No rock is too hard or resistant for some kinds of lichens to attack. At first attaching themselves at microscopic crevices, they secrete acids which dissolve certain constituents so that the rock slowly disintegrates, the rhizoids of the lichen ever penetrating deeper and deeper. Crustaceous lichens may be followed by foliaceous or fruticose species, and these are in turn accompanied or succeeded by certain hardy mosses. Later, the way is easy for ferns and herbaceous seed plants and finally shrubs and trees to establish themselves. A few of the blue-green algæ are able to live in the water of hot springs, but no aerial plants are able to compete with lichens in carrying on life under the most extreme conditions of heat or cold. On the stoniest of blizzard-swept Arctic tundras lichens grow over vast areas to the exclusion of other vegetation, while as already shown deserts and mountain peaks have them in abundance when all other plants are lacking.

A few lichens are of importance because of the harm they do. Certain *Strigulas*, living on the evergreen leaves of tropical plants, are truly parasitic and damage somewhat coffee and other plants of economic importance. One often sees fruit trees with the limbs and twigs densely covered with leafy or shrubby lichens. I do

not believe that they are directly injurious, as long observation of orchards in California has failed to reveal any appreciable difference between trees heavily and lightly infested. But indirectly lichens are injurious upon orchard trees, since they harbor large quantities of more or less harmful insects. Lichens should therefore be removed from orchards by the use of either Bordeaux mixture or lye (caustic potash) solution.

Lastly, let us consider the benefits one may derive from a study of lichens. We may dismiss the probabilities of its leading to fortune and fame, but there can be no question that the true student of these unique plants has a greater opportunity for attaining health and strength than has almost any other devotee at the shrine of nature. Since lichens grow everywhere he will never be at a loss for material and he can gather them at any or all times of year, no matter what the weather. Sunshine, fog, rain, snow, it makes no difference, the lichen collector can take his fresh air constitutional and ride his hobby at the same time. Nor does he only tramp along through forest or prairie, or squat motionless for hours on the old stone ledges outcropping in some hillside pasture. Every atom of strength, agility and daring possessed by the most skillful mountaineers is needed when the lichenist seeks his treasures on Alpine crags among the glaciers or hangs in unstable equilibrium over the verge of some vast sea cliff whose foot is lost to view in a mass of boiling surf. One may even enjoy the climb up some sun-blistered precipice a thousand feet high, rejoicing in new treasures as he draws himself up from ledge to ledge, oblivious to the rattlesnakes who delight to take the sun in such places.

After the field work comes the long hours in one's den where with microscope and specimens one classifies his treasures, coordinates his field notes, and works out problems in ecology, geographical distribution and evolution. But whether he is on the apex of his favorite mountain gazing out over the world beneath while he rejoices in a successful day, or whether he is in his study wrestling with obstreperous specimens which refuse to be classified, he feels amply repaid for his time and effort. It is undoubtedly highly beneficial to man to do some things whose value cannot be estimated in dollars and cents.

The study of lichens satisfies our desire for strenuous muscular activity, often amid the most magnificent or awe-inspiring scenery, pleases our love of the beautiful, appeals to our desire to behold the incredible, and presents some of the most puzzling problems known in the living world to the students of geography, ecology, genetics and evolution.

PSYCHOLOGY APPLIED

By Professor W. V. BINGHAM
CARNEGIE INSTITUTE OF TECHNOLOGY

THIS is the story of an adventure in higher education. Few adventures are less spectacular and more hazardous than those which attempt to introduce something at once useful and new into collegiate conservatism, especially when emphasis in an established science is changed from the academic to the practical—for this was an experiment in directing psychology toward practical ends. These pages tell of the first formal establishment in an American institution of a department of applied psychology, an acknowledgment of the fact that the foundations, at least, of a worthy psycho-technology have been laid.

It is hardly thinkable that this experiment, begun in 1915, could at that time have had the cordial support of the typically traditional university. It had to originate in a youthful and unconventional institution whose frame-work was flexible and whose eyes were on the future rather than on the past. Such a school was Carnegie Institute of Technology. Therefore it is necessary first to describe the peculiar features of this institution, and then to sketch briefly the history of the organization there developed for attacking the problem of how to make psychology useful. On second thought, what could have been more natural or appropriate than that the technology of human behavior should have found a hospitable abiding place, not in a liberal arts college, but in an institution dedicated to the promotion of applied science?

One caution is necessary. No pretentious attempt was made to organize or develop the whole vast territory of applied psychology. The Division of Applied Psychology at Carnegie Institute of Technology has always sharply delimited its scope. It has not approached the problems of abnormal human behavior, criminology, mental deficiency, nor psychiatry. It has not duplicated the activities of the many agencies engaged in the study of childhood and of educational psychology in its applications to problems of the public schools. It has, instead, pointed its energies toward the exploration of promising but unoccupied areas.

This narrative gives, then, the account of an attempt begun seven years ago to direct scientific psychology into the service of

modern business and industry, as well as into channels of usefulness to the students, faculty and administration of this particular institute of higher vocational education.

I

My first glimpse of the institution which was to foster this experiment was on New Year's Day, 1915. Three days previously, at the close of one of the sessions of the American Psychological Association then meeting in Philadelphia, I had been introduced to a short businesslike man with a kindly but somewhat abrupt manner. His card bore the legend "A. A. Hamerschlag, Carnegie Institute of Technology." He wasted no words on preliminaries. "Carnegie Institute of Technology," he began, "is in Pittsburgh. I don't suppose you ever heard of it; but we have a flourishing young institution there. What are you planning to do this week-end, after the meetings? Won't you come and look us over, and then tell us what in your opinion psychology could do for such a technical institution?"

I had indeed heard of Carnegie Institute of Technology, although it was confused in my mind with the older and more famous parent institution across the ravine from it, namely, Carnegie Institute, which includes under one enormous roof the Pittsburgh Public Library, a museum of natural history, a museum of art, and a music auditorium. What I saw on that brief visit must here be recorded as a background for what comes later.

A sunny winter sky greeted me, not exactly what I had expected from the smoking furnaces of Pittsburgh. From the entrance to beautiful Schenley Park I saw a group of monumental public buildings, a civic center remote from the congestion of the business district. On the abrupt heights to the north rose the University of Pittsburgh; less than a mile from it, across a ravine to the south, Carnegie Institute of Technology; and, midway between, dominating the view, the expansive, globe-capped roof of Carnegie Institute.

The Institute of Technology was a revelation. Each of its four colleges occupied a building or group of buildings characteristic of the particular sorts of vocational training they housed.

The Engineering College, or School of Applied Sciences, as it was then called, had power plant and lecture halls, with spacious laboratories for instruction in the fundamental sciences and in civil, electrical, mechanical and chemical engineering. Far below the level of the campus, I saw the metallurgical and mining laboratories beneath which has since been hewn out a demonstration mine. Five stories above, were the headquarters of the department

of commercial engineering, where young men with the foundations of an engineering education were being trained to carry responsibility in the business management of production. Here was a substantial college of engineering, traditional in type, with a few unique features indicative of healthy vitality.

The woman's college, named for the founder's mother, Margaret Morrison Carnegie, reminded me at once of Simmons College, and of the School of Practical Arts at Columbia. Here were white-tiled laboratories of foods and cookery, studios for pottery and lace-making and jewelry, a model apartment, and rooms full of looms, dress-making mannikins, typewriters and accounting machines. If neither the household arts nor the secretarial courses appealed to the student, she might specialize, I was told, in social work and find ample laboratories in the Pittsburgh slums. All the courses, it seemed, were regular four-year college courses, differing from the typical liberal arts curriculum in their vocational specialization. A majority of the girls were fitting themselves to be teachers or public school supervisors of one or the other of these vocational subjects. Obviously, psychology was an essential part of their preparation.

In the Fine Arts College, at first called the School of Applied Design, were sumptuously housed the departments of architecture, painting and illustration, interior decoration, sculpture, music and dramatic art. Superficially nothing could have contrasted more sharply than these elegant studios with the stern laboratories and shops of the Engineering College opposite. The bond of identity lay in the vocational aim. Students pursuing courses in orchestra or in drama, no less than students of mechanics, were bent on fitting themselves to earn a livelihood. One respected the vision of the planners and founders of the institute for putting on a single campus these vocational schools of such contrasted character.

Perhaps the most characteristically distinctive of the four parts of the institution was the College of Industries—then called School of Applied Industries—occupying the original first building. Here one looks down corridors nearly an eighth of a mile in length, flanked on either hand by unit buildings in which are lecture halls and shops, high spacious rooms with equipment for teaching drafting, pattern-making, foundry practice, forge and heat-treatment, and machine shop—all the processes, in fact, which are basic in the machine production industries; in the building-construction industry—masonry, carpentry, plumbing, heating, ventilation, sheet-metal work and electrical installation; and in the printing industry—the fascinating processes of linotype, monotype and hand composition, press-work, multi-color printing and binding. This is not

a trade school, for it makes no pretense to develop manual proficiency and expertness to the point of trade mastery. Instead it does something better. It gives to the high school graduates who take its four-year Bachelor of Science courses some understanding of all the fundamental processes of the selected industry, so that on graduation the way is open to employment, not as a skilled tradesman, but as an assistant to an executive, with assurance that a ground-work has been laid for later success in a managerial or supervisory capacity. In this school also were young men fitting themselves to be teachers and supervisors of manual and industrial arts.

All four of the colleges, then, though differing enormously in appearance, in equipment, and in character of personnel, were alike in having definite vocational objectives that implied a combined technical and cultural training. From forty to sixty-five per cent. of the schedule of most of the students was devoted to studies of the more general or liberal sort, such as English, economics, history, mathematics and science. The happy mean was sought between broadly cultural and narrowly vocational extremes.

This, then, was the picture of Carnegie Institute of Technology when I first confronted the question put by President Hamerschlag as to the place and service of psychology in a technical institution. The schools had at that time been in existence barely ten years. The enrollment varied from about 250 in the woman's college to almost 500 in engineering. The total number of day students was 1,400. A somewhat larger number came to night school, nearly two thirds of these being in industries courses. Altogether, attendance numbered 3,200 students—2,600 men and 600 women; and of these, I estimated that a major fraction were looking forward toward careers in industrial management, social work, teaching, dramatic art, or some other field in which their success would in a measure depend upon their *ability to understand and influence people*. Here then was an obvious service psychology could render: to give to these students such instruction in psychology as would really enable them better to understand and control human behavior.

Students confronted by such a variety of opportunities faced a lively problem of vocational selection. Was it not fair to challenge contemporary psychology with the task of making itself helpful to these students in finding out their special talents and their limitations? This possibility of usefulness was the second to be mentioned in my report with recommendations to President Hamerschlag. I pointed out that as yet the psychological laboratory had made available almost nothing in the way

of adequate technique for helping young people to discover their aptitudes. Long and patient research would have to precede any considerable usefulness of psychology in this regard. But where could this research be better carried forward than in a vigorous young institution which offers on a single campus such varied types of vocational education?

The problem of admissions pointed toward a third possible utility of psychological methods. Could psychological examinations be incorporated as a part of the admissions procedure, to get supplementary information as to the likelihood that the applicant could undertake with profit the work of the Freshman year? I recommended no immediate use of these methods, but instead, a period of trial during which intelligence test-scores and personal interview ratings should be accumulated on all Freshmen, for determination of their predictive value in comparison with high school marks, principals' estimates, and ordinary entrance examination standings.

Still other uses for psychological technique were indicated. Data regarding traits, characteristics and differences in ability would be useful to deans and class-officers in advising students as to their methods of work and their problems of personal development; serviceable also to the placement bureau in getting information as to the type of position for which each senior was best fitted. Educational psychology, to be of use to prospective teachers of the manual, industrial and domestic arts, would call for experimental studies of learning, habit formation and the acquisition of skill. In the Fine Arts College there ought eventually to be a specialist in the psychology of art, who would use the methods of experiment to discover and teach principles underlying both art production and art appreciation. Finally, I urged appointment to the staff of a specialist in motion studies, work and fatigue, in relation to industrial efficiency.

In brief, my proposals grouped themselves around the outstanding problems of selection of students for admission, vocational and educational guidance, and placement at graduation, together with helping to give an insight into human nature to all students whose careers would require ability in understanding and controlling people. President Hamerschlag was well aware of the significance of these problems, and when after a brief interval, he asked me to assume direction of the proposed central department of applied psychology, he cautioned me that a difficult road lay ahead.

Psychology was far from being an unknown discipline in this technical institution before 1915. W. S. Libby taught general and

industrial psychology of the Münsterberg type to the manual arts students, and with one assistant had built up a laboratory with complete equipment for mental measurements of the sort described in Whipple's Manual; and in the Margaret Morrison school two instructors were conducting classes in educational psychology and the principles of teaching, for the young women who were preparing to become public school supervisors of domestic science and art. The new arrangement differed from the old in that there was now established a single central department for all four schools, a department with a fairly well-defined program of service to students, to faculty and to the administration. Service to business and industry, which was soon to become an outstanding feature of the program of the Division, had not yet been clearly visioned.

II

When the newly established Division began its activities in September, 1915, I had four associates: J. B. Miner, from the University of Minnesota; J. L. Zerbe and Katherine Murdock, who had been instructors in the Industries school and the Margaret Morrison Carnegie College for Women; and L. L. Thurstone, a graduate student from Angell's laboratory at Chicago. Thurstone took as his province the learning process and soon initiated experiments in cooperation with the linotype instructors in the printing department. Miss Murdock began the preparation of a scale for measuring merit in sewing, a step which seemed essential as a preliminary to research on the relative worth of rival methods of instruction and training in domestic art. Zerbe continued some studies he had been making on the distribution of grades given in class-room and shop courses. Miner took the problem of getting for the Placement Bureau dependable ratings on seniors in non-intellectual traits. He also examined students individually, and devoted much time to diagnosis and training of two stutterers and of other students who had serious but remediable handicaps of personality. All of us shared in the development and standardization of group tests, for several of which norms were accumulated and reduced to percentile form. Among these group tests were some devised by Thurstone for the purpose of measuring ability to deal with ideas of space relations, an ability without which it would seem to be difficult for a student to succeed in such subjects as descriptive geometry, pattern-making, sheet-metal work, costume design or architecture.

Some equipment was installed, including a Seashore tonoscope for vocational examining in music, an Einthoven galvanometer for research in fatigue, and several tachistoscopes.

The first vocational guidance problem was referred to me by

the Dean of the Industries faculty. A student did not know whether to choose the career of plumber or pianist! The boy was in the building construction course at the time, but restive. He had grown up in a small Pennsylvania town where his father was a dealer in plumbing supplies. He was extremely fond of music and had had a year or two of instruction on the piano. Ought he to drop his present course and aim at becoming the virtuoso of his dreams? I did the best I could to test his musical talent, with such few norms as were then at hand. I secured the judgment and advice of members of our music faculty. And then I had to tell him that as far as we could learn, his chances of becoming a distinguished pianist were nil. He might, in due time, achieve to a position in a café orchestra, but nothing more. In spite of our recommendations, the boy left school to study music under a private tutor, and at last accounts was earning a precarious livelihood giving piano lessons to children. Whether he would have been more happy and useful as a master plumber, who shall say?

The first problem referred to us by the dean of the college for women was that of two advanced students of costume design who were on the verge of failure and elimination. How were we to diagnose their difficulties? We did our best, by personal interview, intelligence examinations and such tests of special aptitude as we could devise. Neither of the girls was stupid; both ranked in intelligence among the middle third of college students. But when I gave them tasks like the reversed clock-hand test and the folded-paper test of the Binet series, one solved them promptly while the other was at a complete loss. The difficulty of the former girl with her school work was one not of ability, but of character. She thought her teachers were unfair and would not apply herself. But with the girl who failed consistently in the form tests, there was little question but that she was deficient in a special ability which is essential in any such subject as costume design, namely, the ability to deal with space ideas. The marvel is that she could have reached the junior year without having become aware of this lack. Thanks in part to the report we were able to give her Dean, she was not dropped from the school, but was transferred to the social work department, where she developed an unsuspected aptitude for work with children.

These are typical of our first tentative moves in the direction of vocational guidance procedures for college students. We yet have far to travel on this road, but appreciable advance has been made since 1915, as is evidenced, for example, by the Thurstone tests for engineering aptitude, with norms gathered from many thousand freshmen.

Miner's Analysis of Work Interests blank is typical of another sort of vocational guidance technique, on which research has been focused since the very beginning of the Division.

Kate Gordon's tests of taste in color and in design and her tests of dramatic insight, on which she worked beginning in 1916 when she first joined our staff, illustrate the effort to measure aptitudes in art activities.

A glance at the annual report of the Division for the first year shows that a start had been made on nearly all of the main portions of the original program. We had centralized in one department the teaching of all psychology and education courses given in the four colleges—a type of departmental organization which has since been adopted for English, mathematics, history, economics and other general or cultural subjects which are essential to any technological curriculum. In research, we had resolutely kept away from certain inviting territories in applied psychology, such as the psychology of advertising and the examination of mentally defective children, because these were being actively cultivated elsewhere. Instead, we were working out methods of helping the deans determine the qualifications of students at entrance, of helping students decide most wisely what careers to choose, and of cooperating with the Placement Bureau in getting information regarding the lines of work for which the seniors seeking positions are best adapted. We were striving to make psychology practical in educational and vocational guidance. In the next section will be told how our efforts came to be directed also toward business and industrial problems of personnel selection.

These, then, were the beginnings made at Carnegie Institute of Technology to erect upon the academic science of psychology a psycho-technology.

III

I had been only a few weeks in Pittsburgh when President Hamerschlag introduced me to a business man of exceptional leadership, Edward A. Woods. Mr. Woods is the district representative of one of the great life insurance companies and is nationally reputed to have the most productive of all life insurance agencies. He was urging that Carnegie Institute of Technology ought to teach courses in salesmanship!

"What is the matter with the courses already offered by the various institutes of salesmanship?" I asked.

"They are all right, but they don't get very far."

"You wouldn't want us, then, to duplicate such courses?"

"No."

"Then before entering this field, we ought to find out more than is now known about selling and salesmen. We should have to learn the difference between successful and relatively unsuccessful salesmen. We ought to study their talents, their aptitudes, their traits, their personal histories, their duties. We should need to gather information as to the potency of incentives and appeals to sales effort and the best methods of selection, development and supervision of salesmen."

President Hamerschlag pointed out that research of the kind required would call for joint effort on the part of a staff of research workers and a group of representative cooperating businesses. And the results might be slow in coming. Patience would be required.

"Do you think the firms that are interested in improving the general quality of their sales force are enough concerned about it to invest real money and several years of cooperation?"

Mr. Woods thought they would be. He cited statistics from sales organizations of national scope to show how enormous is the annual financial loss to business and to the public through employment of new salesmen who eventually fail to make good.

The upshot of the interview was that I prepared a plan for a research bureau to be sponsored and housed by Carnegie Institute of Technology and to be supported by a group of thirty cooperating industrial and business houses, each contributing $500 annually for five years toward the research budget. This budget was underwritten personally by Mr. Woods and two of his friends, Mr. H. J. Heinz, the venerable manufacturer of food products, and Mr. Norval A. Hawkins of Detroit, at that time manager of sales for the Ford automobile. They in turn, with President Hamerschlag's help, secured the cooperation and support of other concerns of national scope, such as Burroughs Adding Machine, Carnegie Steel, Westinghouse Electric, Armstrong Cork, American Multigraph, Packard Automobile and several of the great life insurance companies.

The founding of this Bureau of Salesmanship Research was in many ways a pioneer undertaking. We found little precedent for the proposed form of cooperation between college and business. We aimed to attack with the tools of psychological and statistical measurement a group of problems that had not previously been admitted within the pale of scientific inquiry. It was hard to find men with training adequate to such work, who could be secured for the Bureau staff.

Looking back, now, seven years, it is astonishing to recall the dearth of psychologists with an interest in business problems.

Only two or three in all America had at that time exhibited a competence in practical business psychology which would warrant us in expecting them successfully to direct such an undertaking as the new Bureau. We were fortunate in persuading Northwestern University to give us the loan of Walter Dill Scott, who came to Pittsburgh in June, 1916, as the first American "Professor of Applied Psychology" and Director of the Bureau of Salesmanship Research. Scott's connection with this division during the following three years brought it prestige. His scientific acumen, his exceptional personal leadership and his shrewd, sensible insight into practical business affairs were invaluable aids in the movement to apply psychology to problems of commerce.

The research problem for that first year was the selection of salesmen. Visits to sales managers of the cooperating concerns helped to define the line of attack. The practical experience of these executives was pooled, their methods analyzed and compared. Some experiments in actual selection were tried. The work of the seminar during that year, 1916-17, eventuated in a volume of "Aids in Selecting Salesmen." It included a model application form or personal history blank; an ingenious and compact model letter of reference to former employers; a set of aids in personal interview, designed to focus the interviewer's attention on essential points and to quantify his judgments on those points; and a battery of mental tests with full instructions for giving and scoring. These various "Aids" were issued to the member companies with the expectation that they would be used in employing new salesmen until sufficient data had been accumulated for checking their worth against the criterion of relative sales success.

IV

Then came the war.

The best elements of these group intelligence tests were incorporated with similar materials of Otis, Terman, Yerkes, Wells and others to make up Army Alpha.

The interviewer's score sheets became the "Scott Rating Scale" for selecting and rating officers and officer candidates.

The personal history record, greatly metamorphosed, became the C. C. P. Qualification Card, by aid of which three million men were classified for military purposes according to their occupational, educational and personal traits.

Practically the entire staff of the Bureau of Salesmanship Research and several other members of our Division of Applied Psychology found their best opportunity for usefulness in military psychology or in army personnel work. In the spring of 1917,

Whipple and I served on the committee of seven which prepared the first psychological examination methods for army use. A few weeks later Scott became director and I the executive secretary of the Committee on Classification of Personnel in the Army, and under Secretary Baker's direction, assembled the group of psychologists and employment executives who devised and administered the army personnel system. The first year of the bureau proved to have been an ideal preparation, a rehearsal for the enormous task of military classification and assignment.

If peace had been a preparation for war, war no less prepared for peace. The lessons of experience in dealing with all kinds of men in the army later proved valuable in the renewed task of applying scientific methods to problems of personnel in business and industry.

Selection, classification and development of clerical and executive personnel was demanded, as well as the study of salesmen. The bureau had been piloted during the last year of the war by G. M. Whipple as acting director. He had continued to gather data on salesmen and had initiated investigations of methods of training and supervision. Scott returned from Washington in the spring of 1919, but he shortly relinquished to C. S. Yoakum the direction of the bureau which then took the new name, Bureau of Personnel Research, because its problems and activities had far outrun the original definition of scope. Some of the original cooperating firms withdrew support; others doubled their annual fees, so that the total budget was increased; and still other firms, interested in specific problems, entered into special contracts with the bureau for more research and consultation than a straight membership fee could provide.

The war had wrecked the bureau staff, and Yoakum had to build a new organization, to salvage what he could of the earlier research, and to begin again accumulating data from which dependable inferences could be drawn as to the relative value of various items of information and test data in personnel selection. To-day he can speak with authority on the utilities and the limitations of different methods of selection, of classification and of supervision; and what is more valuable still, he commands the technique of research on these problems. The reports and service bulletins which he and his associates have prepared contain a mine of methods and principles. Mention of only one or two studies must serve here as typical examples.

In the first year of the bureau an experiment with a group of forty salesmen of one of the cooperating companies had yielded

the dismaying results that success in selling for that concern had a correlation with intelligence test scores of zero! There was no relation whatever between demonstrated ability as measured by amount of sales and intelligence as measured by the tests. The results appeared to be a severe indictment of the tests as measures of intelligence. When Yoakum, two years later, first examined these disconcerting data he knew from army experience that the psychological tests had real validity as measures of intelligence; and he solved the riddle. He first took the same data and computed the correlation between intelligence test scores and length of experience with the company. The coefficient was not zero. It was negative, —.40. The brighter the salesman, the quicker, as a general rule, he left the employ of that concern. He gave fresh examinations to seventy-three salesmen in the same company. The correlation between intelligence and length of service was —.46! By accompanying typical salesmen throughout the day, it was ascertained that their work was largely of the routine, order-taking sort. The pay was not large. The chances for promotion were slight. Under these conditions only the more stolid men were content to remain with the company long enough to get valuable experience and build up a creditable sales record. In such circumstances it was possible to determine an upper limit as well as a lower limit on the intelligence scale. Within this range the chances that an applicant for a position with this concern will make good are large. Below this zone he will probably fail for lack of ability. Above it, the chances are that he will not remain in the employ of the company long enough to make a success. The psychological tests were, after all, valid measures of intelligence. The need had been for a scientific determination of the range of their utility. The task of the Bureau of Personnel Research, typical of the aim of the entire Division of Applied Psychology, has been to mingle scientific method and business sense.

The readiness of business men to join hands with a technical institution in such cooperative research undertakings is well expressed in terms of what they are willing to pay toward its maintenance. This cooperation has been increasingly liberal. Little did I think when first we talked in 1916 about support for a research bureau that within a period of six years the Division of Applied Psychology would receive from such sources for its current expenses a total of about $237,000.00. Nor could I then picture clearly the succession of fine, loyal men and women of the faculty whose industry and talent have multiplied for science, for commerce and for society the value of that sum.

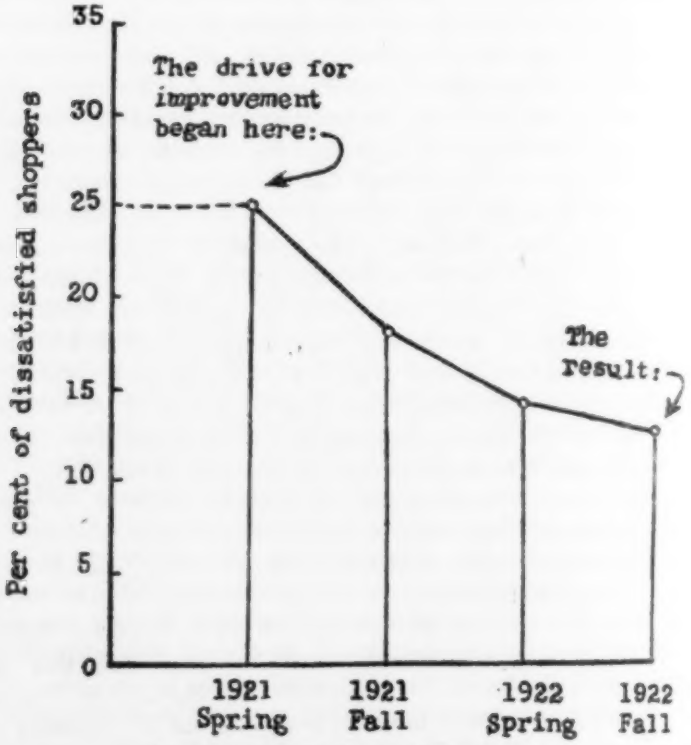
V

Cooperation of business and education on personnel research proved to be a fertile idea. The first of the bureaus soon had a lusty offspring, the Research Bureau for Retail Training.

Among the original members of the Bureau of Salesmanship Research was Edgar J. Kaufmann, a major executive of the largest department store in Pittsburgh. He quickly saw that the general plan of the bureau was sound, but that with its meagre funds and its wide variety of contributing members, it would make but slow progress on the problems which most interested him, namely, those of personnel and training in retail salesmanship. He secured the cooperation of six other Pittsburgh stores, and with them undertook, in 1917, to provide $32,000 annually for a five-year period, for the support of a new bureau to be devoted exclusively to problems of employment, supervision and training in the retail field. The detailed plans were worked out by Miner, who directed the enterprise during its first critical year. Then, in 1918, W. W. Charters came from Illinois to take charge of the bureau, which, if its story were to be told with full account of its achievements, would demand a volume in itself. It has applied the methods of science to the study of store personnel problems of employment, training and supervision. It has prepared training manuals, merchandise manuals, employment tests and specific procedures for correcting defects of sales personality and of supervision. It has worked out retail salesmanship courses for high school use. It has annually trained a small group of graduate students to become either educational directors or store research workers. This bureau has combined psychological insight, research methods and practical business judgment to the end that the public might have an increasingly intelligent and courteous department-store service. Its publications, extensively distributed, are in a small but tangible way modifying for the better the retail sales service of the nation.

How is a business man to know whether this kind of cooperative research pays? The Pittsburgh stores found out by measuring the decrease in the proportion of dissatisfied customers. One of these stores makes on the average about 30,000 sales a day. Inevitably a certain fraction of these purchasers leave the store displeased. The ratio of satisfied to dissatisfied customers has been found by the device of service shopping. Numbers of men and women—mostly women—have been engaged from time to time to make actual purchases of linens, dishes, cloaks and other articles needed, and then later report in detail on the kind of service they have had. The courtesy and interest shown by the sales woman, her knowledge of stock, her personal appearance, her helpfulness,

are all noted. The transaction as a whole, including promptness of delivery, is rated as satisfactory or unsatisfactory. The chart shows what happened in one large store where such service shoppings have been made frequently, beginning in the spring of 1921. Since the store has adopted research bureau methods for increasing courtesy and competence, the proportion of dissatisfied customers has considerably and consistently fallen—an improvement which registers, not only on the balance sheet of the business, but in the approval of the buying public.



MEASURING THE VALUE OF RESEARCH

One store has in less than two years' time cut in half the percentage of dissatisfied customers through improvements in training its salespeople to be courteous and helpful. The training methods were developed and installed by the Research Bureau for Retail Training.

VI

The initiation of the department of Educational Research dates from 1918. Whipple had come on from the University of Illinois for half the year as acting director of the Bureau of Salesmanship Research in Scott's absence; and the following year he resigned

entirely his connection at Illinois and came to Pittsburgh as Professor of Educational Research. His function was not that of the typical student of public school problems. Instead he was to concentrate on problems of higher technical education as they became pressing from time to time in our own institution—problems of admissions, of curricula, of methods of instruction, of administration. His first task was to assemble for the benefit of the entire faculty an exhibit of new examination methods and other teaching aids designed to lighten the instructor's load. Obviously, one man and an assistant could do only a small fraction of the research proposed by the President or pointed out as important by faculty committees; but the rest of us in the division gave him our cooperation. Thurstone took the admissions problems; Miner, the marking system; Charters helped on curriculum research, and also conducted a seminar for inexperienced instructors in methods of college teaching. I worked mainly on administrative problems. E. K. Strong, Jr., coming in 1919 when Whipple went to the University of Michigan, made extensive job analyses of the manager's functions in machine production, building construction and printing concerns, to get light on problems of curricula in the Industries College which trains for executive positions in those industries; and later he undertook research on the study-methods of Freshmen.

One specific task of curriculum building grew out of the work of the Bureau of Personnel Research. In 1919 the original demand was renewed for a short course to train salesmen of life insurance. If such a course were to be prepared and offered, Winslow Russell of Hartford and other life insurance executives would undertake to see that the Institute did not suffer any financial loss. John A. Stevenson, secretary of the University of Illinois School of Education, and Griffin M. Lovelace of the Connecticut Mutual of Hartford were chosen to prepare with Strong's help this curriculum and initiate the course of instruction. Some time the story must be recorded of how, through many months of intensive research, these men organized in detail the five courses which together were to constitute the three months' curriculum. Field practice in actual soliciting, under direction, was introduced as an integral part of the program. This practical experience had to be carefully planned to dove-tail day by day with the lecture and textbook materials of class instruction.

This novel experiment in intensive adult vocational education was a success from the start. Whereas it was quite generally believed in life insurance circles three years ago that it is futile to try by means of a course of instruction to teach salesmen the principles, functions and practice of life insurance, to-day the idea is

widely accepted that a salesman should have some such systematic instruction before he is permitted to offer to prospective customers his counsel on the purchase of life insurance. The American public should be grateful to this course for what it has done toward permanently raising the standard of competence and of professional and ethical attitude among salesmen of life insurance.

For two years my own research interests have included a group of problems in the applied psychology of music. Thomas A. Edison, having invested large sums of money and a vast deal of ingenuity in bringing his favorite invention, the phonograph, to its present degree of perfection, asked us to find out more about the effects of different kinds of phonographic music on the listener. With equipment and assistants which he has supplied, we have classified six hundred selections according to their observed effects on mood, and have carried through a number of experiments on the influence of different types of selection on efficiency in practical activities.

VII

This narrative of origins must hurry past the tempting themes of the years of gradual growth and give in conclusion a cross-section view of the division at the culmination of its sixth year.

Psychology had been brought into the service of students, instructors and administration. Its principles and methods were being applied to vocational education, to educational administration, to commerce and industry.

One department had become seven: The Department of Psychology, the Department of Personnel Administration, the Department of Vocational Education, the Department of Educational Research, the Bureau of Personnel Research, the Research Bureau for Retail Training and the School of Life Insurance Salesmanship. The staff had grown to a total of nine women and men of professorial rank, nine instructors and seven statistical and clerical assistants. A majority of these were financed through funds contributed by business concerns and devoted their first attention to research on applied problems. Out of a total of sixty-five graduate students who since the initiation of the division had been attracted here by the atmosphere of practical science, eight had earned the Master's degree, and two the doctorate. Three were occupying university positions as instructors in applied psychology. Most of the others were in business concerns as research assistants or personnel executives, and the demand for able young men with this type of training had far outrun the supply.

Along with the research work of the Bureaus the main duties

of the staff continued to be to care for the various undergraduate classes in introductory psychology, social, educational and industrial psychology, esthetics, personnel management, advertising and selling. At the same time a small group of graduate students were in training for research and for executive positions in the personnel and training departments of large business and industrial concerns. Their instruction included a grounding in systematic psychology, theory and practice of mental measurement, statistical technique, personnel administration, research methods and such specialized opportunities as are offered from time to time in the several seminars.

The best introduction for a graduate student who wants to fit himself for a career in applied psychology is, we are convinced, not a series of courses in applied psychology, but rigorous instruction in the fundamentals of pure psychology and scientific method, under instructors who are in touch with live problems in both the pure and the applied science, and who can guide the student in his own first approaches toward research on problems of significance to both psychology and industry.

And so a two-fold purpose has guided our plans: to make psychology useful, but also to advance psychology as a science. In studying the effects of music on mood, or the classification of clerical workers according to responsibility, or the teaching of department store clerks to be courteous, or the prediction of student success in engineering, or the differentiation of graduate engineers into those who should be trained as salesmen and those who would succeed better as designers—whatever the nature of the inquiry, we have aimed to solve if possible the immediate practical issue and also to accumulate insight into the psychological principles underlying the observed behavior.

We have found traditional psychology best prepared to be of service, to industry as well as to education, in those sections which treat of the intellect and of learning. But in its treatment of the more permanent trends of human character and action, the psychology of to-day is inadequate. Its attention has hitherto been focused largely upon the structure and nature of the momentary psychosis. Relatively much too small a portion of a typical treatise on psychology has been devoted to exposition of the fundamental impulses, the enduring interests, motives and drives which are at the root of conduct. Too little study has been given to personality, disposition and character and to the emotions and their actual functioning in behavior. Six years' experience in the Division of Applied Psychology made acute the inadequacy of current psychology to explain illuminatingly these non-intellectual

processes which, after all, constitute the most significant phases of mental life.

It is one of our ambitions ultimately to be of some help to systematic psychology in meeting these inadequacies. We have already amassed a large amount of illustrative material, actual recorded instances of behavior in the every-day human relationships of supervisor and employee, of sales person and customer, of instructor and student, a study and classification of which is yielding fresh generalizations for the psychology of habit, impulse, emotion and will. The Division of Applied Psychology has found its justification not only in such service as it has been able to render to industry and education in applying what psychological knowledge was available in 1915; it has also made some progress toward achievement of its secondary aim—that of reinterpreting systematic psychology in the light of new information gleaned here from the applied field.

With the beginning of the year 1921-22 the Division entered into another stage of its history. The name, Division of Applied Psychology, was changed to Division of Cooperative Research, its functions to include the promotion of research in other sciences and technologies as well as in psychology. With this broadened task, however, the present article is not concerned. We need only note that the basic aims remain the same, those of increasing scientific knowledge and of making science useful. The purpose has been and is to serve this industrial community just so far as space, equipment and personnel permit; and at the same time help in bringing to our students that vitality of instruction which comes from teachers in close contact with real present problems of industry.

This adventure in academic organization is still too young to have found as yet many imitators. I know of but one other department bearing the name of applied psychology. Although in other institutions cooperation between science and business has been carried to a high degree of perfection in chemistry, physics, geology and other sciences applied to the improvement of industrial methods, research in psychology for the interest of business is as yet in its infancy. Parts of the Carnegie program have, however, found a ready acceptance here and there. Courses in the psychology of business and in personnel administration are offered under one caption or another in many universities and institutes of technology. The Thurstone tests of engineering aptitude have been used in a score of engineering schools. The brief curriculum for training life insurance salesmen has been taken over in detail by four universities, east and west. In several institutions of

higher learning, business research bureaus have been created by means of which commercial concerns are enabled to cooperate under disinterested educational supervision.

But perhaps only in Pittsburgh, sooty, dynamic center of industrial America, could this movement toward the development of a useful, a practical psychology have found such full expression.

This article has described a concrete attempt to make use of psychology. A vast field of promise, of which these pages hint at a fraction only, lies open to any institution which sets out upon similar adventures in the realm of psychology applied.

SOCIAL LIFE AMONG THE INSECTS[1]

By Professor WILLIAM MORTON WHEELER
BUSSEY INSTITUTION, HARVARD UNIVERSITY

LECTURE VI. THE TERMITES, OR "WHITE ANTS"

THE twenty-one independent social organizations which I have reviewed in the preceding lectures all belong to two natural orders, the Coleoptera and the Hymenoptera, insects so complex and specialized in structure and in their postembryonic development that they are placed by entomologists among the most advanced and recently evolved groups. In order to complete our survey and include the three remaining types of social life, we shall have to turn back to the opposite end of our classification, to the most ancient and primitive orders, the Dermaptera, Embidaria and Isoptera, insects that do not hatch from the egg as specialized and often aberrant and maggot-like larvæ, but as forms very much like the adults, except that they lack wings. Owing to their archaic character, it would have been more natural to deal with these three orders in the first lecture, but I have reserved them till the end because one of them, the Isoptera, or termites, has a social organization in some respects even more highly developed than that of the Hymenoptera and are best understood by comparison with the ants. The two other orders, the Dermaptera and Embidaria, have a very feeble or rudimental social organization and may, therefore, be treated very briefly. They are interesting mainly as showing that social tendencies must have made their appearance very early in the ancestral history of the insects and as indicating that such tendencies may have been rather prevalent among the ancient Carboniferous orders.

The Dermaptera, or earwigs, are peculiar elongate insects, provided with strong forceps at the posterior end of the body, very short, leathery fore wings, or elytra and singular fan-shaped hind wings. Most of the species are tropical and vegetarian, though some are more or less omnivorous or even predatory. The forceps, which differ in the two sexes, are used both in defense and in seizing the prey. We have very few native species of Dermaptera. The common European earwig, *Forficula auricularia*, has been recently introduced into Newport, R. I., where it has become a serious

[1] Lowell Lectures.

pest in gardens and houses, and another large European form, the maritime earwig, *Anisolabis maritima*, is now common along our coast from Maine to Long Island. You will find it abundant at Revere Beach at or near high water mark under the drift wood and débris tossed up by the waves. A very small native species, *Labia minor*, is common in manure heaps, mushrooms, etc.

The earwigs may be included among the subsocial insects because the female carefully guards, rearranges and licks her eggs and even remains with the young for a short time after they hatch. The habits of the common European species have been repeatedly described. The German entomologist Frisch, as early as 1730 and the more eminent Swedish entomologist DeGeer in 1773 recorded the fact that the female cares for her eggs and young. The following more detailed observations on the maritime earwig were published by Bennett in 1904: "When about to lay her eggs the female would make a little chamber for herself in the ground about half an inch deep and one or one and one quarter inches wide. This was hollowed out beneath a log or some other object that rested on the ground. In making this chamber she carried the earth out in her mouthparts, as already suggested, a little at a time, just as an ant would do. She never seemed to use her forceps for either digging or carrying the earth. The chamber is made perfectly clean; no sticks or bits of wood or pebbles are allowed by the more careful females to remain inside. Here she deposits her eggs. In the chamber of one wild earwig I counted about ninety eggs, but none of those I have had in captivity laid quite so many at a time, some laying only twenty-five or less. Immediately after the eggs were laid the female picked them up in her mouthparts, one at a time, and wiped them all over. It looked indeed, as if she rolled them in her mouth. However that may be, when the process is over the eggs are all clean and glossy. Then she places them in a neat pile and stands guard over them. Whether or not it be true with the wild insect, some of the females I have kept for observation have, before their eggs were hatched, moved them all several times from place to place, carrying them one at a time. Some of my earwigs refused to touch food of any kind, so far as I could see, from the time they laid their eggs until the young were hatched, while others would leave their eggs at times to get something to eat. Several times the females, after caring for their eggs a while, have eaten them. I have reason to think, however, that in nearly every case the eggs had already spoiled or dried up before this occurred. The females continued to guard their young for a few days after they were hatched. When, however, they had once left her to seek food for themselves, they could not safely

return lest she should endeavor to eat them. One earwig which I kept in confinement deposited four fairly large batches of eggs in one summer."

The Embidaria (Fig. 93) are a very small order of some 11 genera and 56 described species, confined to the tropics and of an even more archaic habitus than the earwigs. They are rare or local and live in small colonies in peculiar silken webs which they spin in cavities of the soil under stones or on the bark of living trees. The females are always wingless, but the males in some species are dimorphic, one form having well-developed wings, the other being wingless. They feed on vegetable substances. The webs (Fig. 93*c*) consist of tubular, branching or anastomosing galleries and are spun with the fore feet which have peculiar silk-glands in their enlarged metatarsal joints. I have seen these webs in great numbers on the bark of rubber trees in the island of Trinidad and of various forest trees in Guatemala.

The habits of the Embidaria have been studied by Grassi and Sandias, de Saussure, Melander, Perkins, Friederichs, Kusnezov

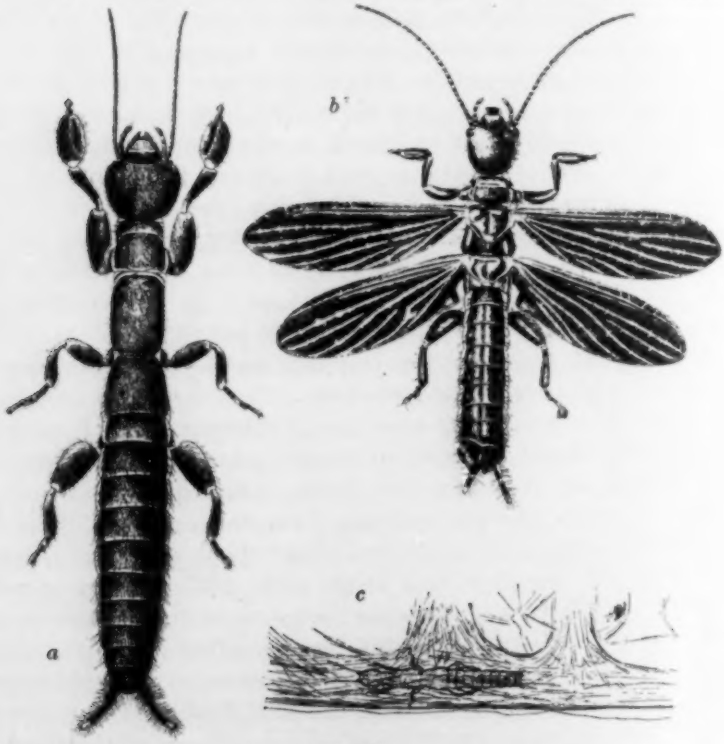


FIG. 93

a, *Embia major* of India, female; *b*, male. (After A. D. Imms.) *c*, *Anisembia texana* of Texas, female in web. (After A. L. Melander.)

and Imms, and we possess two excellent treatises on the morphology and classification of the group by Verhoeff and Krauss. Imms has recently discovered under stones in the Himalayas a large species, *Embia major* (Fig. 93*a* and *b*), nearly an inch long, and has published a full account of its habits. He summarizes his observations on the care of the young as follows: "Maternal care on behalf of the ova and young larvæ is strongly exhibited by the females, in very much the same manner as has been long known to occur among the Dermaptera from the observations of Frisch, DeGeer, Xambeu, Green and others. The female *Embia major* shows very marked solicitude for the welfare of her offspring after her first few eggs have been deposited. She takes up her position in close proximity to the ova and usually concealing them, so far as possible, by means of her body. If alarmed and driven away, she returns sooner or later to take up the same attitude. When the young larvæ are hatched they remain around the parent female, who conceals them, so far as she is able, by means of her body, very much after the same manner as a hen guarding her brood of chickens. A female and her brood were kept in a small glass trough and observed daily living in intimate association. When separated from the parent the larvæ were observed the next day to have regained their former position. As the larvæ approach their second stage in growth, they exhibit a tendency to wander away from the female and construct small tunnels for themselves. They are markedly social, the whole of a brood living together within a complex silken meshwork of tubes."

The resemblances in the habits of the Dermaptera and Embidaria will be sufficiently clear from the foregoing remarks. In both orders there is a feeble tendency to a social organization like that of the dung-beetles considered in my first lecture. It should be noted that the female Dermapteron and Embidarian live for several months after mating, so that in their cases also the first prerequisite for an extension of maternal care of the offspring is realized.

In the Isoptera, or termites, we encounter a social organization of unusual interest, both because it is so elaborate, though exhibited by insects of a very primitive anatomical structure, and because it parallels in so many of its features the social organization of the most highly specialized Hymenoptera. It is as if we had found, when Australia was first explored, the kangaroos and opossums enjoying a social organization like that of man.

The study of the termites began in the eighteenth century with Koenig, who described some of the Indian species in 1779, and

Smeathman, who in 1781 published an excellent paper on some West African species. During the nineteenth century the group attracted few investigators. In 1855-60 Hagen, who was later curator of entomology at our Agassiz Museum in Cambridge, published an important monograph, and Lespès in 1856, Fritz Müller in the seventies (1871-1875), Grassi and Sandias and Haviland at the close of the century (1897-98) gave us valuable accounts of the habits and development of the South European, South American and paleotropical species. During the past twenty years, however, there has been a veritable "boom" in the investigation of these insects. A long list of able workers—Wasmann, Desneux, Sjöstedt, Holmgren, Silvestri, Escherich, Bugnion, von Rosen, Trägaordh, Feytaud, Petch, Imms, Nassonov and Uichanco, in the old World, and Andrews, Knower, Heath, Banks, Snyder, Emerson and Miss Thompson in the United States—have added greatly to our knowledge of the termites. This speeding up of investigation may be gauged by the number of species brought to light since the time of Smeathman. In the early nineteenth century only a few were known, in 1858 Hagen cited 60 forms, by 1904 Desneux was able to list 343 in the "Genera Insectorum," and at the present time the number of described species must be over 1,000. No doubt the greater accessibility of tropical faunas during the past two decades and the increase in the number of well-trained entomologists adequately accounts for this extensive and intensive investigation, for the termites are nearly all tropical or subtropical insects, and being soft-bodied and rather unattractive have never appealed to the amateur who delights in collections of beautiful pinned specimens. We have only 38 species of termites in the United States and only two of them reach the latitude of Boston.

The recent ransacking of the tropics by the specialists above mentioned has led to a much more satisfactory classification of the Isoptera. According to the latest and best arrangement, devised by Nils Holmgren, the order may be naturally divided into four families, the Mastotermitidæ, Protermitidæ, Mesotermitidæ and Metatermitidæ. All the species are social, but the four families show a progressive development in the order mentioned and in both structure and habits, from primitive and generalized to more advanced and specialized forms. I shall refrain from annoying you with taxonomic details, but I must dwell for a moment on the Mastotermitidæ, which have the same interest for the termitologist that *Pithecanthropus erectus* has for the anthropologist. The family Mastotermitidæ was established by Froggatt for a single species, *Mastotermes darwiniensis,* from Northern Australia. A study of its structure shows that it combines characters peculiar to the

cockroaches on the one hand and to the true termites on the other. Its general habitus is cockroach-like, and it has distinctly 5-jointed tarsi and an anal lobe to the fore wing, cockroach characters which do not appear in other termites. At the same time, as Holmgren has shown, this insect is not so clearly related to the modern Blattidæ, or cockroaches, as it is to their ancestors, the Protoblattidæ, which became extinct in the Permian. We are therefore justified in regarding the termites as primitive social cockroaches, which probably came off from the ancestral blattoid stem in late Paleozoic or early Mesozoic times. Some light is also thrown on the significance of Mastotermes by a study of the fossil termites. Although we have no paleontological records of these insects before the Tertiary, von Rosen has been able to discover four extinct species of Mastotermes, three (*bournemouthensis, anglicus* and *batheri*) in the Eocene and Upper Oligocene of England and one (*croaticus*) in the Miocene of Croatia. This indicates that the genus, now confined to Northern Australia and reduced to a single species, once contained many species and was distributed throughout the continents of the Old and probably also of the New World. Other termite genera are abundantly represented in the Baltic Amber and in the Miocene formations of Colorado and Europe, and von Rosen has shown that they belong to the two lower families of the higher termites, the Protermitidæ and Mesotermitidæ, the highest family, the Metatermitidæ, which builds the extraordinary nests in the tropics at the present day, being absent from the early Tertiary formations. This does not mean that the Metatermitidæ did not exist at that time but that the European climate during the Oligocene and Miocene may have been too cool for them. Even to-day they are almost exclusively confined to the warmest portions of the earth. In all probability, therefore, the termites, like the ants, reached their complete structural and social development in the late Cretaceous or early Tertiary and have since undergone very little modification.

It is difficult for the inhabitants of temperate regions to appreciate the great importance of the termites in the tropics where they may, at least locally, equal or even surpass the ants in the number of their colonies and individuals. Even the casual visitor to the tropics will be impressed by the abundance of ants, but he may never see the termites, because the wingless members of their colonies rarely expose their pale, thin-skinned bodies to the light and air, but keep them carefully concealed under the soil, in covered galleries or in the dead and rotting vegetation. He may be astonished to see the dark-colored, winged, sexual forms suddenly appear at certain times in great numbers, but unless he is an entomologist,

he will probably regard them as true ants. Closer observation, however, reveals the fact that the activities of the termites are both extremely helpful and extremely injurious to man. In South Africa Drummond long ago found that they perform an important function like that of the earthworms in moist temperate regions, but on a vaster scale. Since they are so very numerous and feed almost exclusively on dead vegetable substances they conspire with the bacteria, high temperature and humidity to accelerate the disintegration of all the lifeless plant matter and to convert it into humus which can be at once utilized by the growing vegetation. The termites are therefore important agents in assisting the growth and renewal of the great rain-forests of the Amazon, the Congo and the East Indies. But even in the dry savannahs of South America and Africa and the open forests of Australia they hasten the dissolution of the dead grasses and other herbaceous plants as well as that of the sparse bushes and trees. On the other hand their insatiable appetite for cellulose and anything containing it makes these insects a terrible menace to all wooden construc-

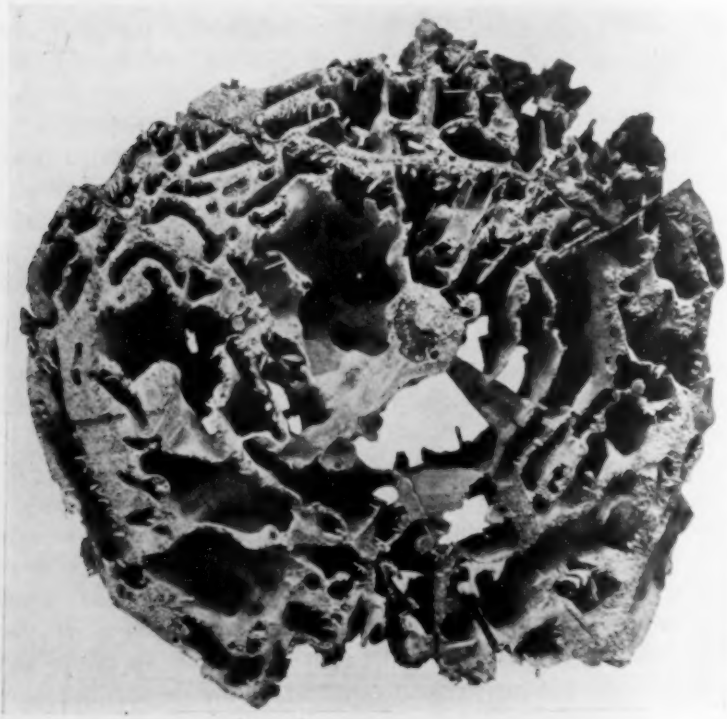


FIG. 94

Damage by *Calotermes hubbardi* to rafters in an "adobe" building in Arizona. (After Thos. E. Snyder.)

FIG. 95
Book from the library at Van Buren, Arkansas, ruined by termites. (After Thos. E. Snyder.)

tions, such as fences, telegraph poles, houses, railway ties, bridges, furniture, ships, fabrics and books (Figs. 94 and 95). They do millions of dollars worth of damage annually. It has even been claimed that their fondness for literature is in part responsible for the slow cultural growth of many tropical countries. Alexander von Humboldt states that he rarely saw books more than 50 years old in Northern South America. The termites have undoubtedly obliterated so many of the records of human achievement that they must be regarded as the subtlest enemies of the historian and archeologist. The damage is so serious that progressive tropical communities are now beginning to use stone, cement and iron instead of wood in the construction or at least in the foundations of buildings.

Termite, like wasp, bee and ant colonies, show an increase in population as we pass from primitive species, such as the Protermitidæ, to such highly specialized form as the Metatermitidæ. Thus the colonies of Calotermes, Archotermopsis and Termopsis consist of only a few dozen or a few hundred individuals, whereas those of the higher termites may comprise hundreds of thousands. Andrews estimated the number of individuals in a moderately large colony of *Eutermes pilifrons* as 631,878. The populations of some African, Indian and Australian Metatermitidæ probably run into the millions.

The polymorphism or caste development is strikingly like that

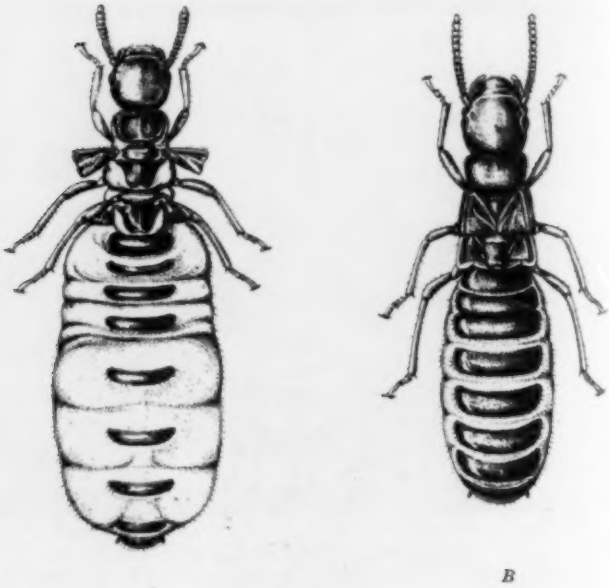


FIG. 96

Reticulitermes flavipes. *A.* Old, deälated, physogastric, first form queen. *B.* Old, deälated, first form king. (After N. Banks and T. E. Snyder.)

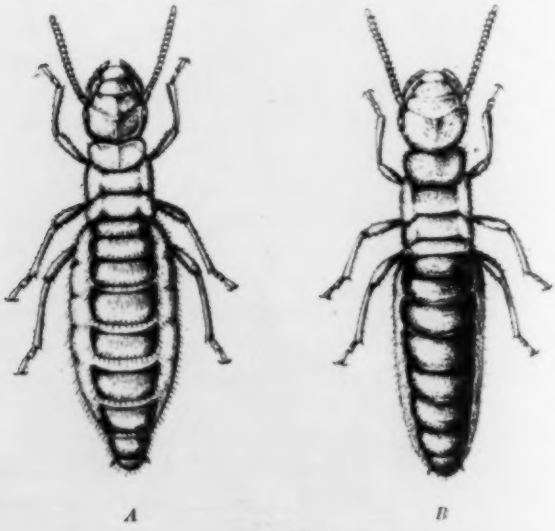


FIG. 97

Reticulitermes tibialis. *A.* Incipiently physogastric, apterous queen of the second form; *B.* Apterous king of the second form. (After N. Banks and T. E. Snyder.)

of the ants, but closer study shows that the resemblances really conceal remarkable and complicated differences. In ants we distinguished only three or four castes: males, queens, workers and soldiers, the last appearing only in certain species. Only one of the castes is male and is socially unimportant, while the three others are exclusively female. In the termites both sexes are of equal social importance, because each caste comprises individuals of both sexes, though they are almost or quite indistinguishable externally. In the great majority of species there are five castes, three of which are fertile and two sterile. They may be briefly characterized as follows:

1. *First form adults* (Fig. 96), usually called kings and queens. They are very similar, deeply pigmented insects, with large compound eyes, large brain and frontal gland, well-developed repro-

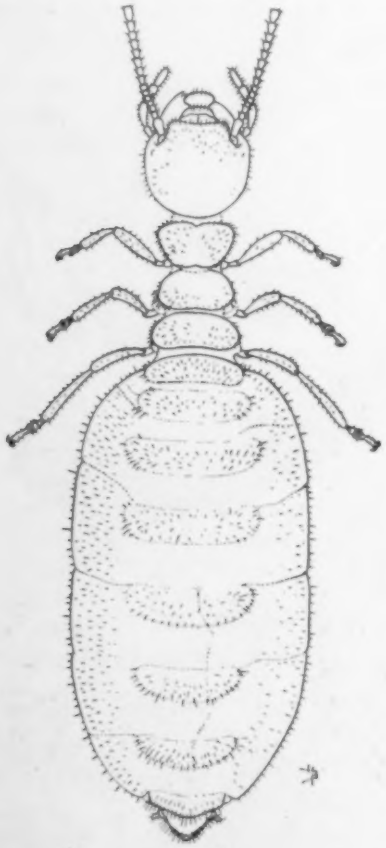


FIG. 98

Mature, apterous, third form queen of *Reticulitermes flavipes*. (After N. Banks and T. E. Snyder.)

ductive organs and at first with well-developed wings, but these later break off at preformed basal sutures and are discarded. Old individuals of this caste therefore can always be recognized by the truncated wing-stubs.

2. *Second form adults* (Fig. 97), sometimes called neoteinic, complemental, or substitutional kings and queens. Less pigmented, with wingpads, or incipient, nonfunctional wings; brain, compound eyes, frontal gland and reproductive organs somewhat smaller than in the first form.

3. *Third form adults* (Fig. 98), sometimes called ergatoid complemental or substitutional kings and queens. Scarcely pigmented; entirely wingless. Brain small; eyes and frontal gland vestigial; mature reproductive organs smaller than in the second form.

FIG. 99

Leucotermes tennis of the Bahamas. X2. *a*, worker; *b*, soldier; *c*, physogastric queen; *d*, king.

4. *Workers* (Fig. 99*a*). Wingless, unpigmented; brain small, compound eyes and frontal gland extremely small or absent; reproductive organs embryonic, non-functional. Head broader than in the first and second adult forms.

5. *Soldiers* (Fig. 99*b*, Fig. 103). Wingless; head large and more or less pigmented; brain very small; compound eyes vestigial; head, frontal gland and in many species the mandibles and

mandibular muscles large (mandibulate) soldiers. In a few genera the soldier caste is represented by a different form, usually smaller than the worker, with retort-shaped head, produced anteriorly in the form of a long, tubular snout, with the opening of a large frontal gland at its tip. This form is known as a "nasutus."

The following deviations from this typical series of castes may be noticed. In some Protermitidæ (Calotermes, Archotermopsis, Termopsis) the worker caste is absent and its place is taken by the young soldiers and sexual forms. In another genus, Anoplotermes, the soldier caste is absent though typical workers are present. In some genera (Eutermes, Rhinotermes, Acanthotermes, Capritermes, Termes) there are two or even three different types of soldiers, and in a few genera (Synacanthotermes, Termes) there are two different types of workers. Hence we have the following eight castes, each represented by males and females and therefore making 16 different kinds of individuals:

1. First form males and females (true kings and queens).
2. Second form males and females.
3. Third form males and females.
4. Large male and female workers.
5. Small male and female workers.
6. Large male and female soldiers.
7. Medium-sized male and female soldiers.
8. Small male and female soldiers.

Probably no single colony of termites ever produces all of these castes, but five or even six of them are frequently represented. Attention should be called to the fact that the soldiers and workers are really larval (nymphal) forms that have been arrested in their development and peculiarly differentiated in certain characters. The second and third adult forms are also arrested, at least so far as the development of their wings is concerned. Owing to the fact that their bodies are still immature or larval, though their reproductive organs may be functional, they have been regarded as "neoteinic."

Although the origin and meaning of the various castes in termites is a matter of considerable interest and has given rise to much discussion, I shall have to treat it very briefly. It was formerly supposed that all termite eggs were alike and therefore produced young larvæ which were at first the same but took on the various caste characters as a result of differences in feeding (trophogeny). Recently, however, Bugnion and especially the late Miss Caroline Thompson of Wellesley have shown that the castes are at least to an important degree determined in the egg. Miss

Thompson found that the very young nymphs or larvæ on hatching may be divided into two series, one with larger, the other with smaller brain, eyes and reproductive organs, and that the former give rise to the reproductive, the latter to the soldier and worker castes (Fig. 100). In all probability even closer study will show that each of the three reproductive and each of the two sterile castes may be distinguished at the time of hatching by certain slight internal characters. The observations of Miss Thompson and Snyder also indicate that each of the adult sexual forms can reproduce itself and the forms below it in rank, but not those above it. Thus the first form adults or true royalty can reproduce all the castes, the second form adults can reproduce their own form, the third form, the soldiers and workers, and the third form adults can reproduce only themselves, the soldiers and workers. The soldiers and workers are normally sterile, but sometimes they become fertile and on such occasions probably reproduce only their

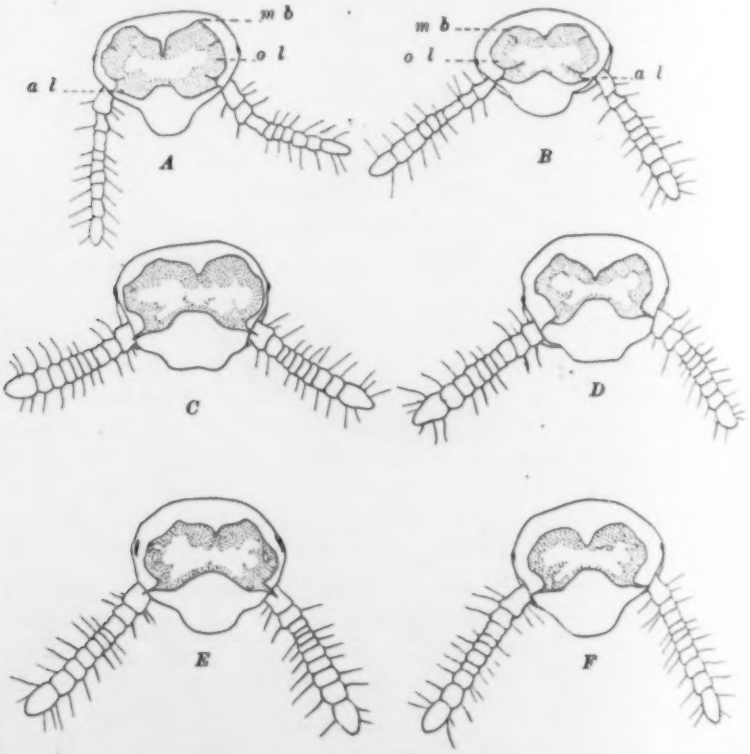


FIG. 100

Sections of heads of young termites to show relative size of brain and eyes. *A, C* and *E*, just hatched reproductive forms; *B, D, F*, just hatched worker-soldier forms. *mb*, mushroom body of brain; *ol*, optic lobes; *al*, antennary lobes. (After Caroline B. Thompson.)

own castes. It would seem, therefore, that the various castes, except the first, are really mutations, partly fertile and partly sterile, and comparable with the series of mutations which certain plants tend to produce in each generation (*Oenothera Lamarckiana*). This brings us back to Darwin's discussion of neuter and sterile insects in the eighth chapter of the "Origin of Species," where, referring to the garden stock which produces single and double flowers, he says: "According to M. Verlot, some varieties of the double annual stock from having been long and carefully selected to the right degree, always produce a large proportion of seedlings bearing double and quite sterile flowers; but they likewise yield some single and fertile plants. These latter, by which alone the variety can be propagated, may be compared with the fertile male and female ants, and the double sterile plants with the neuters of the same community. As with the varieties of the stock, so with social insects, selection has been applied to the family, and not to the individual, for the sake of gaining a serviceable end." If further investigation, as now seems likely, extends Miss Thompson's interpretation and shows that each termite hatches from the egg as a recognizable member of a particular caste, we shall have to revise our views on caste differentiation in the ants, because the same explanation may apply to them. It is, in fact, not improbable that the caste of a particular ant is likewise determined in the egg, but special feeding of the larva may be necessary to bring it to maturity. The passively fed ant-larvæ are certainly very different from the active termite nymphs, which soon after hatching are able to run about and seek their own food.

The social functions of the various termite castes correspond to those of the analogous castes among ants. The dark-colored, winged kings and queens, soon after reaching maturity, suddenly leave the nest in a swarm and fly up into the air. This has been called a nuptial flight from analogy with the flight of the male and female ants, but as it is not accompanied by mating, it is more properly called a flight of dispersion. The kings and queens after spending a very short time in the air, alight on the ground, throw off their wings and associate in couples, the king running along after the queen. As soon as they find a convenient spot each couple digs a small chamber (Fig. 101). Both insects work together on its excavation, and it is not till their habitation is completed that mating occurs. The whole termite colony is the offspring of such a royal pair, just as the ant-colony arises from the single fecundated queen. In the lower termites the queen undergoes little change in shape since she produces few eggs and those at rather long intervals, but among the Meso- and Metatermitidæ, which keep their

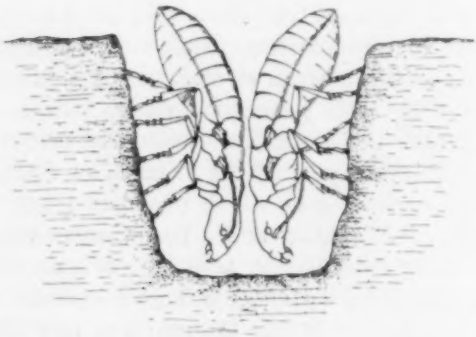


FIG. 101

Young king and queen of *Hodotermes turkestanicus* beginning to dig their burrow in the soil after the dispersion flight. (After G. Jacobson.)

king and queen in a special royal chamber in the middle of the termitarium, the queen's abdomen swells to extraordinary dimensions as a result of the amount of food she is given and the enormous growth of her ovaries and fat-body (Fig. 99*c*, 102, 103). In some species of Termes she may attain a length of four inches and 20,000 times the volume of one of her workers. Escherich,

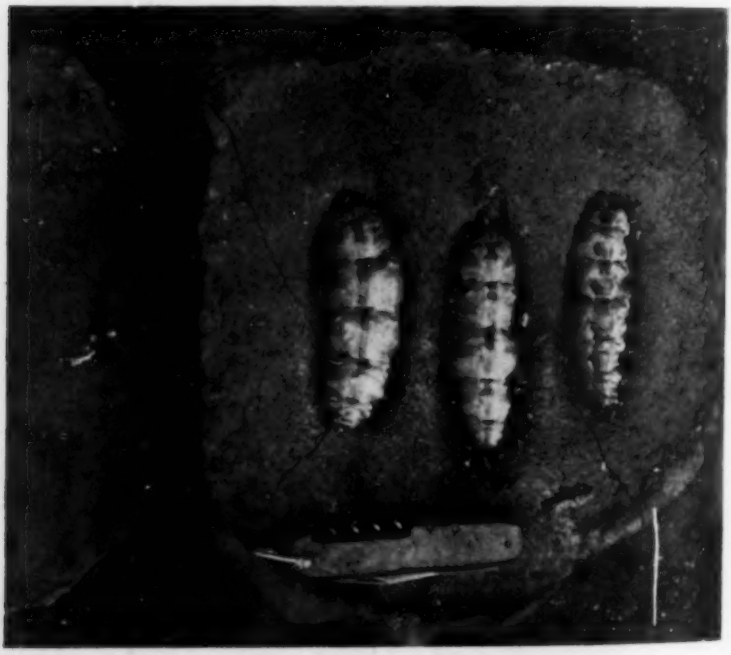


FIG. 102

Three physogastric queens of *Termes*, sp. in the same royal chamber. (From a photograph taken by H. O. Lang at Niangara in the Belgian Congo.)

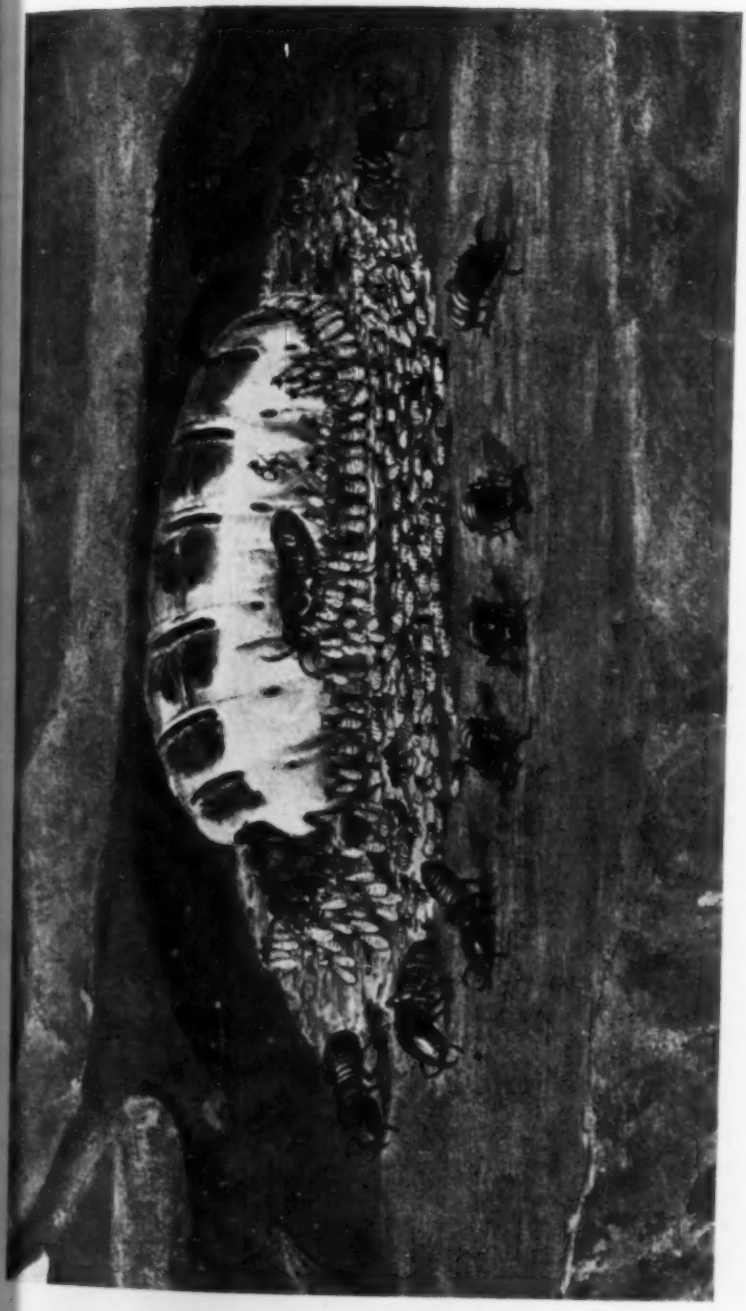


FIG. 103

Scene in the royal chamber of the African *Termes bellicosus* showing the king, physogastric queen and the attendant soldiers and workers. (From a water-color drawing by G. Kunze. After Prof. Karl Escherich.)

who has studied the fertile queens of various Abyssinian and Indian species of Termes, gives a remarkable description of their machine-like—he calls it factory-like—oviposition. Since one of these queens lays an egg every few seconds with clock-like regularity, he estimates that she must lay about 30,000 a day, 10 million a year and 100 million during her lifetime of about ten years. Certainly the Termes queen outrivals in fecundity any other terrestrial animal.

The second and third form adults are usually interpreted as substitute royalty, *i. e.*, as forms which may take the places of the true king and queen if they happen to die. Fritz Mueller found in the nest of a South American Eutermes a true king with a harem of 31 queens of the second form, and Holmgren describes another South American termite, *Armitermes neotenicus*, in the colonies of which he constantly found a true king with a harem of about 100 females of the second form. The Swedish investigator believes that in this species true queens are no longer produced.

The function of the worker termite is, like that of the worker ant, mainly concerned with feeding and cleaning the other castes and constructing and repairing the nest. The soldiers of the mandibulate type are evidently defense organisms which use their powerful jaws like the soldiers of ants, but the nasuti, which are usually smaller than the workers and have vestigial mandibles, resort to a different method of fighting. Andrews, who studied the behavior of *Eutermes pilifrons* in Jamaica, says that the nasuti "are potent defenders of the community, at least against other communities. Nasuti were seen to attack alien nasuti and workers by thrusting their snouts against and close to the enemy and ejecting a minute amount of liquid from the tips. This liquid is perfectly clear and colorless. . . . When a coverglass was held over excited soldiers this secretion was collected as if by squirting across space. When drops of it were injected by the soldier onto the heads of other soldiers and workers it seemed to produce a sort of paralysis, which in some cases was connected with the adhesion of the antennæ to the head. . . . The secretion seems to act merely mechanically to stick legs, etc., till the foe was powerless."

The feeding habits are very complicated. Although dead wood and other dead vegetable substances are gnawed off and ingested by the individual termites, they have also developed a very elaborate system of mutual feeding (trophallaxis). They feed one another with saliva, with regurgitated, partially digested food (so-called stomodæal food) and with food that has passed through the alimentary canal, *i.e.*, with feces (proctodæal food). But even this

does not exhaust the nutritive resources of these extraordinary insects. Holmgren finds that all the castes produce exudates, that is, fatty substances which, arising from the fat-body and blood-plasma, exude through the thin chitinous investment of the abdomen onto its surface and are licked up by other members of the colony. There seem to be as many different kinds of exudates as there are castes, and probably the castes are recognized by their taste. The physogastric queen produces the most delicious and the most copious exudate and is therefore constantly surrounded and licked by a host of workers (Fig. 103). According to Escherich, her exudate is so attractive that the workers in order to make it flow more abundantly will even tear little strips out of the royal hide. He also states that many old queens bear the scars of such treatment as small brown spots or freckles on their milkwhite bodies. We have seen abundant evidence of trophallaxis among the ants and social wasps, but in none of them is it so elaborately developed as in the termite colonies, the members of which may be said to be bound together by a circulating medium of glandular secretions, fatty exudates and partly and wholly digested food, just as the cells of the body of a higher animal are bound together as a syntrophic whole by means of the circulating blood.

(To be concluded)

FIESTA AT SANT'ANA, NEW MEXICO

By ELSIE CLEWS PARSONS

IN Keresan towns saint's day dances are almost the only dances open to whites, and they attract visitors, all told, in large numbers. And yet aside from a slight account by Lummis of the dance on July 14 at Cochiti I know of no description of these dances at all adequate for either tourist or anthropologist, for both of whom they are full of interest. They are a very vivid expression of historic continuity or, if you prefer, of what sets up when two different cultures come into contact, two cultures or rather three—Pueblo Indian, Spanish, "American."

The pueblo of Sant' Ana is a mission of the Franciscans at Jemez, several miles north, up the Jemez river. The padre had not only to hold mass on the morning of his visit to Sant' Ana; there was a baby to baptize and two graves to bless. As the padre walked into town, leaving the buggy in which one of the devout had brought him across the wash and the drought-dried river bed, the church bell was sounded—knocked with a stone, a substitute for a missing clapper. Several young women who were graduates of the Sisters' schools in Santa Fé or Bernalillo greeted the padre cordially in English. Outside the sacristy the padre was greeted also by the four Sisters who had come up from Bernalillo to sing, and, in Spanish, by the *sacristan* of Sant' Ana and the *fiskales*, church officers of Spanish days.

Burials are still made in Sant' Ana in the churchyard,[1] the graves unmarked by mound or cross. The church faces south, so the grave is orientated north and south.[2] As the padre read the service, while several men stood in a half circle at the foot of the grave, a woman and child[3] joined them. From their heads the men removed their *banda*.

Into the baptistry a baby was carried by its *madriña*, and the very elaborate baptismal ritual of the church was performed. I had not realized how likely to impress a ritualistic people this

[1] In attempting to establish a cemetery elsewhere or even to enlarge the churchyard the Church meets with grave opposition.

[2] In several pueblos—Zuñi, Acoma, Isleta, Taos—people will not sleep orientated as in burial. Among the Hopi where there is no churchyard burial there is no aversion to sleeping in any position. Orientation in burial and in sleep has been of Spanish provenience.

[3] In the west, *i. e.*, at Zuñi and among the Hopi, women and children do not attend a burial.

Catholic ritual must ever have been, with its applications of oil and of water to the various parts of head and body, *its rite of breathing upon the infant*,[4] the numerous prayers with frequent change of vestments and use of lighted candles. In holding the candles and in responses to the prayers a *fiskale* assisted. There was no *padriño*. The child had been born some time before St. John's day; for the time being a closer reckoning was not possible, and there was no father of record. "For my grandchild," said an older man in offering his coin to the padre.

The water was poured on the head of the infant from a metal container in the shape of a shell—medicine-water is commonly administered in Pueblo ceremonial from a shell and in the baptistry stood a portable wooden niche for a saint's image which in construction and coloring was extremely suggestive of the altar frames of Zuñi societies.[5] The lower parts of the panels were painted white, the upper part green-blue or yellow, with diagonals between the parts of the white and black block pattern, used so much not only on Pueblo altar frames but on the kachina masks. On top of the niche was a design of a sun in red banded with semi-circular lines of yellow, blue, red and white, the usual color circuit association.

The image of Sant' Ana rested on a table in the middle of the church. Under the table was a large and handsomely decorated pottery water jar, and propped against the table were three of the "officers' canes."[6] Many candles stood on the ground in front,

[4] Expiration figures in native curing ritual, and head washing in native initiations and other ritual.

[5] The esoteric organizations for curing or weather-control to which a large number of the townspeople belong.

[6] The "officers in a Keresan pueblo are the governor and his lieutenant, three "war-captains," and a varying number of *fiskales*. They are appointed annually, by the native hierarchy which is the real government of the town. The "officers" are a Spanish institution which has served the hierarchy as a go-between with the whites.

A Spanish or Mexican town official is possessed of a stick or cane of office *(vara)*, and the Pueblo "officer" came into one. President Lincoln, tipped off by some one who was unusually well informed, presented all the Pueblo governors with silver headed inscribed canes, a rarely intelligent gift.

Like the *vara* (or the sceptre) these canes have a fetichistic character. They are still blessed, *i. e.*, aspersed in some of the churches on Kings' Day (January 6) and in one town they are even sprinkled with prayer meal.

Pueblo societies and persons holding ceremonial office may also be possessed of sticks of office. At Laguna I have heard of the "war captains" placing their canes on native altars. "They are a protection," just as no doubt these Sant' Ana canes (probably the *fiskales'*) were thought of as a protection to the saint. Her improvised altar, canes, water jar, and manner of placing the candles were all together not a little suggestive of native altars. Better had the saint been placed on the ground, but the table was the Spanish of it.

and these were added to by several worshippers who, before placing down their candle and lighting it, would touch the saint near her heart or on the beads around her neck. One old man, arrayed in a Mexican poncho of blue cloth, a type of shirt rarely seen to-day, and shaps of yellow kid or buckskin, having placed his candle in the most conspicuous position in front of the saint, knelt on both knees behind it during the entire service. Afterwards he walked in the procession on the right hand of the padre. Probably he had taken a vow. Not long since at Jemez, the padre told me, the father of a little boy, lost in the mesas, had vowed that if the child were recovered, he would serve as *padriño* to the *santu hijo* (godfather to Jesus) during the following Christmas, fulfilment of which meant giving costly entertainment to many visitors. From motives comparable, entertainment is given to the kachina at Zuñi by the entertainers of the *shalako,* bestowers of beloved offspring.

To return to church at Sant' Ana—on the floor opposite the becandled saint were placed many baskets of produce, twenty or more, mostly wheat in the grain, some with rolls of bread on top, and in one basket were piled ears of dark blue or black corn.[7] Here, too, were lighted candles; in their flicker the richly colored offerings made a very pleasing show. Above it, painted on the white wall of the church, were two great tasseled stalks of corn and two more on the church wall opposite, all four designs rising out of the stripe in color of red soil running around the base of the walls. Do not the saints as well as the kachina bring crops, since they bring rain? It had always rained, I was told, the afternoon of the fiesta of Sant' Ana.

On the wall near the church portal hung what at Cochiti used to be called "God's whip," a wooden handle with holes at either end, for loop to hang by and for the knotted hide thong. The whip hangs on the wall, but it is no longer used at Sant' Ana, where formerly, as at Cochiti, it figured in the summons of delinquents to mass by *fiskales.* Were the jucca switches of the kachina suggested by "God's whip" or, perhaps, by the jucca lashes of the Penitentes?

At the close of mass the drum outside the church was beaten and guns were fired off. The procession started: first, the saint carried by four girls, her cotton panoply attached to four poles, supported by four men, then a crowd of worshippers, then the padre, habited now in his brown Franciscan cowl with corded belt and in sandalled feet, on his right the solemn old man dressed in his Spanish heirlooms, behind them the four black habited Fran-

[7] This is the colored corn which is given as tithes, so to speak, to the Town chief, the so-called cacique or head of the hierarchy.

ciscan Sisters, and straggling last, three or four "Americans," one, God forgive him, with a camera.

The Franciscan Sisters led the singing, processionals now in Spanish, now in English. The circuit was characteristically anti-sunwise, from church door in the east northward, westward, southward, then down the plaza, the Middle as the townspeople say, to the bower of spruce, the saint's house, at the north end. At the cardinal points in the route cottonwood branches had been planted, and at each point for a few moment the procession halted.

The saint is placed in her house of green, her followers disperse, in the plaza appear six *koshare* to dance in line abreast up and down the Middle. Their bodies are bent forward as they caper with arms now and again outstretched. Posture and gestures are like those of the *koyemshi* of Zuñi or the Hopi *wöwöchimtu* or the Jemez *tabösh* or the Black Eyes of Taos, and their singing likewise reminds one of those other clownish groups, buffoons and burlesquers and potent withal in the hierarchy.

Two of the *koshare* wear grey skull caps, streaked in black, the others have their long hair parted and tied up on either side with a bunch of corn husks. Face and body are painted grey, with black stripes, three black rings around arms, body and legs, and eyes and mouth black encircled. They wear dilapidated moccasins and a ragged loin cloth or apron to which sheep toes are attached as rattles. Under both knees is tied black yarn. In both hands spruce twigs are carried. Around the neck is a string of yellow berries, the Jerusalem cherry.

After this dance it is dinner time, and there is going and coming from house to house and around the two booths some Mexicans have installed to sell sweet drinks, candy, etc. On a house ruin near me stands a group of young men to whom another Mexican is trying to sell some Navaho silver ornaments. "Mal fiesta, mal fiesta," he grumbles as not a boy takes interest in his ware. . . . The dancers are assembling in the two estufas,[8] and from one to the other old men pass, carrying dance paraphernalia, and the *koshare* who *go down the ladder head foremost*.[9]

[8] The estufa (Spanish) or kiva (Hopi) is a kind of club house, where dances or ceremonies may be held, and which is used more or less as a lounge or workshop by the men. All Keresan towns, except Acoma, have or had a double estufa system, the two estufas commonly called Squash and Turquoise. Children, boys and girls, go to the estufa of their father, a woman, after marriage, to that of her husband. The societies have their own separate meeting places, but the dancer kachina groups and the clown societies make use of the estufas.

[9] As do at times some of the Zuñi masked dancers or kachina, in imitation, they say at Zuñi, of the woodpecker, a bird associated with the war cult, and these are warrior kachina.—Many war traits attach to the phallic clown societies whose historical connection with the military societies of the Plains Indians may some day, I think, become clear.

From the hatchway of each estufa projects the standard that is to be carried in the dance. The head of the standard is a gourd painted green with an encircling block pattern of white and black. Above and below are fringes of red horse hair, on the very top a bunch of parrot feathers, and over them hawk or eagle feathers. Below the gourd is a kilt of native cloth, and a long strip of native cloth to which eagle feathers are fastened extends half way down the pole. It is a gay and stylish standard used in all Keresan church fiestas, and a like standard is carried by the Sun society of Jemez, which sings for the women's harvest dance. That the standard was raised from estufa hatchway while preparations were going on within is quite analogous to the placing of a standard in the hatchway in Hopi ritual.

Some drums are also to be seen on the estufa roofs—painted carmine on the southwest estufa towards the river, Squash estufa, and violet blue on the estufa on the northeast side of town, Turquoise estufa. . . . The Turquoise estufa dancers are out first, to dance up to a position in front of the church. Ahead is carried the standard with the dancers behind, two men, two women and so alternating, couple by couple.

The men wear Hopi dance kilt with Hopi belt of heavy knot and long fringe and at the back the pendent foxskin. Bells are tied with yarn under both knees, spruce twigs encircle the belt, and spruce is carried in the left hand, in the right, a carmine gourd rattle. They wear olivella shell necklaces and over their moccasins skunk-skin heel bands. Legs, arms and hands and upper body are painted a violet blue (a commercial dye, alack, which is being used, I am told, for the first time) and down the back are in darker tint four zigzags. The hair of some of the younger men and boys is short (another unhappy Americanism), of the older men, flowing, in the hair of all on top is a bunch of parrot feathers.

The women dancers wear their native cloth dress, the ugly calico slip happily tucked away, leaving arms and left shoulder bare. They are barefoot, in each hand spruce twigs, on each cheek a round of red paint.[10] Their hair is flowing, surmounted by a *tablita* of turquoise painted wood cut on top in the double cloud terrace design, at each of the four corners two turkey feathers, the feathers ever associated with the dead and with rain-makers.

There are several dance figures, a song to each figure, with a short pause between. In one there are two rows of women in the middle, the rows of men on the outside; another figure is down the middle and back like a reel; in another, two rows, men and

[10] That this fashion, not uncommon in the get up of women dancers, is of Mexican provenience Lieutenant Simpson gives testimony. "Not unfrequently they [Mexican women in New Mexico] are covered with a red pigment in blotches," giving "to the face a frightful and disgusting appearance." *Reports of the Sec. of War*, p. 133, *Ex. Doc.* No. 64, 1850.

women alternating, face each other and then in groups of four or six break up to dance in a circle and return to place. The choir dances up and down in irregular lines, before the church on the right of the head of the dancing lines, in the plaza, on the left. The singers carry spruce in their hands which are painted the same violet-blue. A piece of spruce is stuck behind in the belt of the drummer. Spruce is indispensable to the saints' dancers as well as to the kachina.

The dancing before the church concludes, and as the dancers walk away in single file they pass close to the other dance set coming in from Squash estufa. The Squash estufa dancers and choir resemble the other estufa set in all particulars but the color of their paint, which is carmine. In both dance sets there are from forty to fifty dancers, with about fifteen singers in each choir.

We leave the Squash estufa people dancing before the church and follow the Turquoise estufa people in to the plaza. Down the Middle they dance until they take position before the saint's bower and repeat all their dance figures, which takes about forty minutes. At one time the standard bearer leaves the choir to manipulate his standard with a quivering motion over the head of the mid-line dancer, the dance leader. . . . After this first dance before the saint every dancer enters her house to say a prayer and *to breathe from her*, a native breath rite. Several dancers place food offerings by her table, one girl drapes over the saint's shoulders a silk kerchief, an indispensable part of gala dress and a gift highly acceptable to any Pueblo woman.[11]

Again as the Turquoise estufa group walks out, the Squash estufa group comes in, dancing. From now on alternation in the plaza by the two groups will continue until sundown; but the padre is desirous of being monastery bound, after all, his part is over, and so we leave town. Again in his honor the bell is aclang, its sounds mingling with the far carrying notes of the choir, singing repetitiously,

> ***hama kaach, hama kaach!***
> **Long ago it rained, long ago it rained,**

words quite appropriate, as it happens, to that long season of drought, which, despite the boast of customary rainfall, neither the dance we have just seen is to break nor yet the dance a few days later in honor of another saint, Porcingula, once of Assisi, then of Pecos, now of Jemez. The first rain of the season falls the day after the Water Serpent is brought from his spring into Jemez to the altar of the Flint Society.

[11] Taos women excepted, since they alone of Pueblo women do not wear the kerchief across the shoulders, without which, if she went outdoors, says the Zuñi woman, she would feel naked and ashamed.

THE SOCIAL SIGNIFICANCE OF THE ARMY INTELLIGENCE FINDINGS

By Professor PERCY E. DAVIDSON

STANFORD UNIVERSITY

THE spectacular significance of the army intelligence data is found in their damaging consequences for certain pivotal articles of faith in the American social-political tradition. Because they demonstrate, at best, an adolescent mentality for the masses of the people, the traditional democratic aspiration for a social order resting upon an enlightened and cultivated general will must be renounced. Obviously a relatively childish mentality can not support institutions presupposing rationality and refinement. By implication society must be governed, however circumspectly, by the gifted minority. Because they have shown that class and income levels reflect a natural biological stratification, modern democratic movements looking towards the leveling of inequalities in income, social prestige and social power are doomed to futility and but serve to incite the less well-to-do to irrational discontent and reckless revolt. Because of the limitations of natural endowment on the part of the multitude, elaborate and costly programs for universal education are illusory and wasteful, and should be circumscribed in the interests of the more able. If the army intelligence findings justly support these serious strictures upon currently accepted notions, certainly their importance has not been exaggerated.

They do so only when three assumptions are first regarded as securely established: one to the effect that the army draft was truly representative of the American population at large; the second predicating that the tests employed were tests of native intellect rather than of cultural achievement; the third implying that the native intellect in question is so general in its nature as to condition social success or social achievement of any significant kind.

As to the representative character of the army draft there have been differences of opinion, since accurate knowledge is not at hand. It is noted in the official report[1] that the effect of defer-

[1] "Psychological Examining in the Army," Memoirs of The National Academy of Sciences, Vol. XV.

ments and exemptions was such as to make "the tendency of the selective service act to send men to camp who on the average are probably slightly inferior to the average of the general population." A reading of the list of occupations reported will show that the army draft was not thoroughly representative of American industrial society. The distinctly greater number of the designations refer to artisan trades; there is a considerable number of clerical occupations and a scattering of the semi-professional. The great farm-holding group seems not to have been represented by the category "farmers," apparently made up chiefly of unmarried farm hands. The independent business community was similarly not represented. Such members of these groups as entered the service presumably became officers of one sort or another or joined the subsidiary relief and welfare organizations. These groups contain something like 30 per cent. of the working population and quite possibly have in them a disproportionate share of abler individuals. It will thus be seen why the scores of the draft are not regarded as picturing faithfully the intelligence of the general population, and why the reservations of the official report may very considerably understate the amount of the discrepancy. The presumption is, consequently, that generalizations from the selected groups do not accurately carry over to the general public, and so fail to do justice to its intelligence.

But a much more hazardous assumption is that which assigns to the army tests the power of reaching beyond the effects of training and of measuring native intellect. It is now a commonplace in the discussion that innate differences are known only when opportunities for practice have been equalized. This is to say that a test or examination *per se* can never be regarded as a test of native capacity. It is such only under highly favorable circumstances, these obtaining—if they ever do—when the physical and social environments have from birth made equal demands upon those who take the tests. The conceivable subtlety and delicacy of these demands and the consequent differential effects in accumulated habit might well be stressed here in connection with the whole problem of mental testing, but the applications for the army results are primarily in question. Some relevant data may be briefly reviewed.

The Alpha examination contains tests that bear heavily upon familiarity with language, knowledge of number and general information—all matters that may be thought of as strongly affected by unlike conditions on the several social levels. When the distributions for each of the component exercises of Alpha are examined, it appears that only two of these approximate the normal curve and

these two not closely. For all of them the frequencies pile up on the lower scores, and it is noteworthy that the most frequent score in six of the eight tests is zero, a frequency that outnumbers the next largest several times in some tests. This means that an important fraction of the draft was unprepared to make one point on these tests, which leads the compilers to the natural inference that many of the poorer scores were made by persons handicapped by experience rather than by stupidity. The distribution of the Beta component tests are likewise suggestive of factors other than native talent. The language handicap in this test for foreign-born illiterates as compared with English-speaking illiterates has been definitely noted.[2] As for the negroes, so many of whom were examined by Beta, the consensus of opinion among the examiners was that this examination was not well adapted to their type of mind. Of a representative group of 1,216 men who failed in both group examinations and were recalled for individual testing, 49 per cent. of whites and 75 per cent. of negroes could neither read nor write; 39 per cent. of the whites and 59 per cent. of the negroes had not reached the first grade of school. More than half were "farmers," presumably from outlying and backward communities. The number free from disease was small. Nevertheless, 45 per cent. of whites and 44.6 per cent. of the negroes were placed in regular service and a median weekly wage of about $15 was reported for the whites.[3] Now if such were the circumstances of those failing to pass the group examinations, it is very probable that those making the lower passing scores were seriously handicapped in the matter of social experience and that their native ability was not fairly exhibited. To make the limitations of language and schooling wholly a consequence of an imputed stupidity flies in the face of all the probabilities, for we know as a matter of fact that persistence in school reflects not ability alone but family tradition, incentive to mental improvement, economic status and cultural opportunity as well.

That the scores in these examinations are materially affected by social experience is attested by certain other lines of evidence. An appreciable rise in them was found to accompany length of residence in this country on the part of the foreign-born, amounting to two years of mental age when the first five-year interval is compared with the fourth. There seems little reason to suppose that the first-comers were more able than their successors. With respect to the nativity of the foreign-born, "the range of difference

[2] Myers, *Journ. of Educ. Psych.*, April, 1921.
[3] "Memoirs," Part 3, Chap. II, Sect. 2.

is a very high one. Among the men from England only 8.7 per cent. were rated D or less, while among the Poles the percentage making these low ratings was almost 70. In general, the Scandinavian and English-speaking countries stand high in the list, while the Slavic and Latin countries stand low" (p. 699). The disparity here is so great in amount as to suggest other than selective factors at work. The great differences are shown between languages most removed in kinship, which coincide with the most marked differences in the extension of popular education and popular culture. It is to be noted, furthermore, that the ratings of the negroes as a group are astonishingly low as compared with other obtained indices, and that the northern negroes are superior to the southern. Correlation of schooling with "intelligence" for the draft as a whole seems to have been as high as .75. In none of these data is it necessary to deny the presence of native differences. They are, however, such as to encourage caution in accepting the results as anything like precise measures of native capacity.

Studies of the influence of practice in the Alpha examination are of interest in this connection. College seniors who were given four forms of Alpha at intervals of three weeks showed striking improvement in the second and third trials. The practice effect for the lower half of the group was much greater than for the higher, indicating that the lower scores were in greater degree affected by the novelty of the tasks.[4] Similar results were obtained from retests in army groups with Examination *a*, which is of the same general nature as Alpha. One notes with interest that in a group of 190 enlisted men the letter-grade remained the same on the second trial with only 56 per cent. of the cases. The suggestion of inequality of practice antecedent to the taking of the tests in these observations is of first importance in the comparison of social classes. The natural inference is that the obtained scores from one trial, as well as the averages based upon them for occupational levels, are uncertain indications of what would hold in measures of capacity where equality of practice could be assumed. Sympathizers with those psychologists who contend that differences in the power *to learn, to acquire, or to improve by practice*, are the really substantial differences among individuals will hesitate to accept indices of native capacity derived from single performances where the antecedent practice is essentially unknown. It is just in this inequality of practice in all exercises highly subject to training that the experience of the several social levels is most unlike, with the obvious consequence that the lower or compara-

[4] Dunlap and Snyder, *Journ. of Exp. Psych.*, 1920, 3: 396.

tively unschooled classes suffer from an undue depression of their scores in such exercises.[5]

Significant facts bearing upon the influence of experience in the Alpha examination appear in a special study of some 2,500 medical officers believed to be representative of the profession.[6]

In this study the average positions taken by officers of several different branches of service in the eight component exercises of the examination were compared and so-called psychographs for each branch were determined. A few incidental observations will illustrate the nature of the findings. In Test 8, dealing with rather indiscriminate items of general knowledge, for instance, it appears that the engineer officers and the chaplains fell upon the same percentile for all branches of service. But in Test 2 and Test 6, dealing with numbers, one finds the engineers holding a position twice as high as that of the chaplains. On Test 4, on the other hand, which relates to dissimilarities and similarities of words, the position of the chaplains is at the 80th percentile while the engineers' is found at the 62nd. Test 3 calls for the choice of the best answer to questions implying some scientific knowledge and inferences from it. Here the discrepancy is less and favors the engineers. Other tests perhaps call upon less specially trained functions. Probably no one will seriously contend that with the five of the eight tests referred to there was anything approaching equality of antecedent practice in the two vocations compared—native differences being left aside. One is therefore left in doubt as to the part played by native endowment in so small a group of tests, and the doubt carries over to the seventy occupations of the army draft. Did not the tests strongly favor, probably, the clerical occupations as compared with manual, and is the disparity in the averages for these two great groups of workers so large as the scores would indicate? And may we not fairly assume that there was in general a far greater proportionate amount of antecedent practice and habituation in all the upper-level occupations in the exercises of these tests?

Significant for their bearing upon this matter of the incidence of culture upon the army Alpha scores are the following coefficients showing the measure of correlation found with forty-one American states as between the median scores for at least 500 draftees and the social-economic conditions indicated. Only white men are involved in the comparison.[7]

[5] On the reliability of single trials see Otis, *Journ. of Educ. Research*, 1921.

[6] Cobb and Yerkes, *Bulletin National Research Council*, Vol. I, Pt. 8, No. 8, 1921.

[7] Alexander, *School and Society*, September 30, 1922.

TABLE 1

Showing the coefficient of correlation for 41 American states in Army Alpha and

1. Per cent. of foreign-born	.65 ± .06
2. Per cent. of native-born of native parentage	—.61 ± .07
3. Per cent. of urban population	.62 ± .07
4. Per cent. of homes owned in rural states	.68 ± .07
5. Per cent. of farms owned in rural states	.66 ± .07
6. Wages for farm labor in rural states	.88 ± .03
7. Per cent. of literacy	.64 ± .06
8. Ayers' Index to State School Systems	.72 ± .05
9. Three, five, six, seven and eight (above) combined	.89 ± .02

While a sufficient faith in the existence of innate differences among American states may conceivably enable one to construe these coefficients without disadvantage to Army Alpha scores as measures of endowment for large social groups, it is probable that impartial minds will see in them confirmation of Davies' similar findings for production of persons of distinction. In fact a coefficient not reported in the above list for Army Alpha with one of Davies'[8] rank-orders involving 29 states, is .79 ± .05.

It thus becomes evident that the averages for the social groups studied by means of the army tests, whether of nationality or occutional level, must be conceived as recording in considerable part the differential effects of unlike social experience. For aught one knows to the contrary these averages may record such effects *only*, leaving intact an historical assumption, as plausible hypothesis at least, that the greater social groups in modern societies are essentially equally well endowed. At any rate it would seem necessary to go outside the army data for the decisive testimony.

Turning to the third assumption underlying the application of the army findings to the general population, we inquire as to the relation of the army-examination "intelligence" to those native abilities which "urge and enable one" to achieve in the activities of life at large. From the statistical nature of the occupational distributions Kelley infers "that factors other than general intelligence are very largely operative in determining selection of a vocation."[9] His coefficient for the test intelligence with these other factors is as high as .875. The study of the medical officers referred to above found no correlation of the test-intelligence with income from the practice of medicine. Whether it should or not, it is evident that society does not reward medical service in proportion to this type of intelligence. A high positive correlation was found in the army data with rank among enlisted men. Of the officers,

[8] "Social Environment," 1917.

[9] *Journ. of Applied Psych.*, Vol. I, 1917, p. 50.

it is stated, "On the whole it seems safe to say that among officers outside the Medical Department intelligence differences according to rank were, at the time and under the conditions of the testing, of no psychological significance" ("Memoir," p. 858). The obtained coefficients with academic grade among high school and college students range from .30 to .50 and average around .40, indicating that many other factors are at work in this preparatory type of social activity. Certainly the social significance of the army test-intelligence is not impressive on this meager showing, although their faithful devotees will doubtless contend that this is less a criticism of the tests than it is of the discrimination of the public.

The uncertainty which has been shown to envelop the three major assumptions upon which the use of the army data has been based for the characterization of the general population tends to minimize the importance of much of the current criticism of the democratic philosophy these data have inspired. A brief comment may be made upon those aspects of this philosophy touched upon in the opening paragraph.

Even if it should turn out from competent psychological investigation that average human endowment has been unduly magnified historically, it may still be asserted with all possible emphasis that no one knows what this average endowment is capable of achieving. What is known of its history from savagery to the existing measure of civilization speaks well for its future. The declaration that the average man can become a Darwin needs no refutation. But to deny him the capacity of appreciating civilization well enough to conserve and advance it through democratic methods, in behalf of a more harmonious and more admirable social order, is sheer dogmatism and not scientific inference from any evidence now at hand.

As to the biological stratification which is alleged to explain and justify existing class and income inequalities, very little can now be stated with certainty. A judicial review of the data relating to the class origin of persons of distinction does not sustain this view of the social structure. The economists have shown that existing income curves are absurdly at variance with the normal curve which would describe, presumably, the distribution of native ability. The much-quoted conclusions from the very few unrelated studies reporting the results of testing children of fathers on the several social levels require substantiation, both as to the competency of the tests, and as to the numbers and classifications of the subjects, to deserve a small part of the significance credited them in this connection. As a matter of fact the newer data from

the tests still leaves the discussion about where the probabilities of current theory put it. This is, in the mind of the writer, at a moderate degree of correlation between native ability and class position. The correlation is probably still less when income levels are in question. The reasoning is as follows:

If the upper social levels contain a larger share of native ability this must be due to the effect of one of two conditions, or of their combination. The one is the possibility that as each generation becomes adjusted to the social-economic system, it is sifted and sorted on the basis of its potential abilities, so that the more gifted persons tend to occupy the upper social levels, the less able to fall upon the intermediate levels, and the least able to settle towards the bottom. This process—designated as the "social ladder"—would favor a high correlation between native ability and social status. But there is also to be noted the supplemental effect of heredity in passing on to children some measure of the ability of the parents. If, therefore, the social ladder has operated with effect in earlier generations some part of the correspondence would be maintained. The coefficient of correlation between parent and child, as these have been ascertained from the studies of the biometricians, gather about .50 and fall in some cases to .30, which seems to mean that, as marriages go, any position above the average of the general population that a father may hold by virtue of his endowment, has already been reduced one-half in the son—on the average. The few ascertained grandparental coefficients are still lower, ranging from .15 to .30. The conclusion would be that in groups so large as social classes the effect of heredity in maintaining class differences in native ability must be confined to two generations following the original selection, and is really emphatic in one only. If there are forces at work tending to nullify more and more the effect of the social ladder, it would seem that any existing correspondence between ability and social status must tend to disappear. Such forces are at work in any country where the land and natural resources become increasingly inaccessible to the whole population by reason of their absorption into private holdings with the right of bequest, or wherever economic opportunity is withheld from ability either by direct favoritism or by a selective process of training based primarily upon family resources.

As for the situation at any given period in any country, it is evident that the correspondence of ability and economic level will depend upon the immediate history of that country. If conditions have been such as to provide wide opportunity for the operation of the social ladder within a generation or two, we should expect to find some such correspondence. In the United States a very

great industrial expansion has taken place within a period that involves no more than three generations. The frontier has been closed only within this period. At the same time a tremendous accession to the population has taken place, especially of immigrants of all degrees of ability presumably, who were thrust into a field of unexampled opportunity. It is almost inconceivable that a premium has not been placed upon ability in such circumstances. While the operation of the social ladder may be slowing down, as some students intimate, it does not appear likely that its earlier influence has as yet been spent, or that it can be completely nullified if the industry of the country continues to expand.

An important bit of evidence bearing upon the operation of the social ladder in this country, as it affects the large agricultural group, has been made available in a study of the careers of 2,112 present farm-owners in five mid-western states.[10] Of the whole number 25 per cent. received their farms by inheritance, 23 per cent. by purchase from a near relative. Thus 48 per cent. rose to farm ownership with the assistance of their families, freed in part from the competition which by hypothesis selects the more able for the higher economic levels. If it does not require extraordinary ability to acquire a farm by marriage this figure should be raised by 8 per cent., making 56 per cent. in all who were aided.

If it be assumed that this group is representative of the farmers of the country, and the further assumption be made that the aided 56 per cent. were sons, grandsons, or nephews of men who achieved farm ownership under pioneer conditions through their own exertions, it is possible to believe that the aided portion of the group inherited a measure of, but not an equal amount of, superior ability from their antecedents—if it in fact required exceptional ability to build up a farm under pioneer conditions. The 44 per cent. who attained to farm ownership without ostensible assistance may plausibly be credited with ability above the average, or at least above the average of farm hands. When all these assumptions are made the conclusion runs to the effect that farm-holding status is correlated with some measure of superior ability when the group is compared with farm laborers, and conceivably with economic groups of a higher status.

There is no knowing to what extent the situation in agriculture is typical of the industry of the country. But the picture suggested from this scant evidence is hardly one that would take form if the social ladder has been acting with drastic effect. The element

[10] W. J. Spillman, "The Agricultural Ladder," *Proc. Amer. Econ. Assoc.*, 1919, p. 170.

of economic assistance is too conspicuous and the force of heredity too uncertain to encourage belief in a close correspondence of ability and economic level. The probabilities seem to favor a moderate degree of correlation.

The amount of assumption and inference in this argument obviously deprives it of any special weight. It may perhaps have the merit of suggesting that the setting-up and perpetuation of biological superiorities and inferiorities along social-economic lines, so easily assumed in current accounts of the matter, is subject to conditions which require for their understanding elaborate sociological researches that have not as yet been made.

The implications for universal education are not obscure. Doubtless the gifted minority should be discovered, wherever it may happen to reside upon the social levels, and be given all possible encouragement. Traditional wholesale methods of schooling have been quite too negligent of this precious element in the population, and economic resourcelessness often hampers it. But it surely does not follow that the great majority should be denied any training by which it can possibly profit, because of an arbitrarily imputed stupidity. Scientific methods of training have not as yet been inaugurated either for the one group or the other. If the potentialities of average endowment are known only when they are thoroughly exploited, any neglect of them will be as wasteful from the viewpoint of the largest social good as would be the neglect of the highly endowed.

THE MATHEMATICAL SCIENCES IN THE LATIN COLONIES OF AMERICA

By Professor FLORIAN CAJORI
UNIVERSITY OF CALIFORNIA

THE early history of the mathematical sciences in America, especially in the Latin colonies, has received little attention at the hands of scientific men. It is the aim of this paper to pass in rapid review the early observations in astronomy, mathematics and physics made before 1800 in the French, Spanish and Portuguese possessions in America. By confining ourselves to the time since Columbus, we shall omit descriptions of the number-systems and calendars of the American aborigines; we mention here only the calendar of the Maya of Central America who had developed a wonderful number-system on the principle of local value, with a symbol for zero, about the beginning of the Christian era, or *several centuries before our Hindu-Arabic number-system was invented.*

1. *Astronomical determinations of geographical positions.* The period of geographical discovery with its long ocean-voyages demanded measurements to determine what place on the earth's surface the explorer had reached. Except for short expeditions, the daily records of speed and direction ("dead-reckoning") of a ship were inadequate. These data were supplemented by astronomical observations. The latitude of a place was much easier to determine than the longitude. An easy method consisted in measuring the angular altitude of the North Star above the horizon. An instrument, such as the astrolabe, which measured the angle between a line pointing directly to the North Star and a vertical line would suffice. In course of time various instruments of successively increasing degrees of precision came to be invented. Columbus used an astrolabe; so did many later navigators. The astrolabe was well adapted for finding roughly the meridian altitudes of the sun, but the latitudes computed from them with the aid of the early tables of the sun's declination were unreliable because of the inaccuracy of the tables. In 1867 an astrolabe was found on an old portage road at the Ottawa river in Canada which, most probably, belonged to Champlain and was lost by him in

1613.[1] On June 7, 1613, Champlain speaks of the difficulty of making a portage, which must have been at or near the place where the astrolabe was found. Before that date he records determinations of latitude regularly in degrees and minutes; after that date he gives only rough estimates in degrees. This fact was probably due to his loss of the astrolabe previously used in his measurements. The instrument found in 1867 was a circular brass ring 5⅝ inches in diameter, each quarter of which was divided into degrees, ranging from 0° to 90°. When held in suspension by a small ring attached to the edge, the 0° marks were at the top and bottom, and the 90° marks at the extremities of the horizontal diameter. A movable index, turning on the center, carried two sights. When the instrument was freely suspended by the small ring and the index was pointed to a star, the angle which the index made with the horizontal diameter gave the angular altitude of the star. This astrolabe weighs about three pounds and is kept as a precious relic of the time of French-American exploration.

A slight modification of the ordinary astrolabe was the nautical or astronomical ring; instead of the movable index it had a hole in the rim through which a ray of light from the celestial object passed and fell upon the inner graduated edge, thereby indicating the altitude of the object. Father Kino (whom we shall mention again later) in 1701 made determinations of latitude at the junction of the Gila and the Colorado rivers, near the present town of Yuma, by the use of an astronomical ring (anillo astronómico) as 35° 30′; in 1538 P. Nadal had estimated this latitude by the meridian altitude of the sun as 35° 0′. C. Delisle in his maps adopted the value of 34°. In 1774, Father Juan Diaz made it 32° 44′ and in 1775 P. Pedro Font,[2] 32° 47′. One of the early needs in exploration were maps. The determination of distances and relative positions called for measurements which before the advent of clocks and telescopes were necessarily very crude. The French geodesist, La Condamine,[3] in 1745 refers to a map of the region of Quito, engraved in 1707 by the German Jesuit missionary, Samuel Fritz. Condamine says: "Father Fritz, without clock and without telescope was not able to determine the longitude of any point. He had only a small half-circle of wood, three inches in diameter,

[1] O. H. Marshall: "Champlain's Astrolabe" in *Magazine of American History*, Vol. III, p. 179. See also A. J. Russell *On Champlain's Astrolabe*, Montreal, 1879; Slafter's edition of *Champlain's Voyages*, III, pp. 64-66; H. W. Hill, *The Champlain Tercentenary*, Albany, 1911, p. 57.

[2] Manuel Orozco y Berra, *Apuntes para la historia de la geografía en México*, Mexico, 1881, pp. 423, 326.

[3] De La Condamine: *Relation abrégée d'un voyage fait dans l'intérieur de l'Amérique Méridionale*. Paris, 1745, p. 13 *et seq.*

for finding latitudes; finally he was ill when he descended the river to Para. One has only to read his manuscript journal, of which I have a copy, to see that many obstacles then and after his return to the mission did not permit him to make the observations necessary to make his map exact especially toward the lower part of the river."

The difference in longitude between two places can be found by noting the exact times of an event visible simultaneously at both places—an eclipse, for instance; the difference of these times gives easily the difference in longitude. If in an eclipse of the moon, the shadow of the earth is seen at one place to touch the moon at 9 P. M. and in another place at 10 P. M., the difference in time of the two places is one hour and the difference in longitude is one twenty-fourth of 360°, or 15°. This method goes back to the time of the Greek Hipparchus. But in early days the determinations of longitude were often absurdly inaccurate. When on his second voyage, Columbus observed at Haiti in September, 1494, an eclipse of the sun and made a calculation which placed him 18° or about 1,200 miles too far west.[4] On October 6, 1541, Antonio de Mendoza, first viceroy of New Spain (Mexico), wrote that by observing two lunar eclipses he had found the difference in time between Mexico City and Toledo in Spain to be 8 hours 2 minutes 34 seconds. This yields for Mexico[5] a longitude which is in excess of the true value of 25° 42′ 42″. This determination remained the accepted value during the sixteenth century. The eclipse of the moon of September 23, 1577, was observed in Mexico City and also by Tycho Brahe at Uraniburg, and by various astronomers in other places. From the data thus obtained it followed that Mexico City was 104° 45′ west of Paris—a very accurate figure for that time—being less than 4° in excess of the true value.[6] Other determinations were wider from the mark, so that the figure adopted for maps of about 1601 were 7° in excess of the true value. An eclipse of the moon was observed at Huehuetoca, situated in the same meridian as Mexico, on December 20, 1619, by the Dutch engineer Enrico Martinez. That eclipse was carefully observed in Europe and yielded greater precision of many geographical locations. The various observational data were gone over by Fray Diego Rodriguez of the University of Mexico, the immediate predecessor of the famous Cárlos de Sigüenza; Rodriguez reached the conclusion that the city of Mexico was 101° 27′ 30″ west of Paris.

[4] J. Winsor: *Narrative and Critical History of America*, Vol. II [1886], p. 99.

[5] Manuel Orozco y Berra, *op. cit.*, pp. 150, 151.

[6] Manuel Orozco y Berra, *op. cit.*, pp. 312, 313.

This result was very satisfactory for that time, exceeding in accuracy the value reached by Alexander von Humboldt about a century and a half later and differing by only 12 seconds of time from the modern figure of 101° 27′ 18″ due to Francisco Diaz Covarrúbias.[7] Rodriguez's determination of longitude did not become known in Europe, where geographers of the eighteenth century placed the longitude of Mexico as high as 106° and 107° 30′. The latitude of Mexico was fixed at the time of Cortés at 20°. Among the best eighteenth century determinations was that of Antonio Leon Gama. This modest but accomplished scientist was born and educated in Mexico. He studied the works of Newton, Wolf, Gravesande, Musschenbroek, the Bernoullis and Lacaille. He was connected with the school of mines in Mexico, calculated and observed eclipses of the sun, made determinations of longitudes and latitudes, and prepared a dissertation on the aurora borealis. He was highly esteemed by Lalande, who secured the publication of Gama's scientific results in the *Connoissance des temps* in Paris.

But eclipses of the sun and moon do not occur with sufficient frequency to satisfy all practical needs. Nor is the weather always propitious when eclipses do occur. If the two stations are far apart, one let us say at the Greenwich Observatory or at Paris, and the other somewhere in America, the comparison of time observations would meet with long delay (unless ephemeris are available) on account of the slowness of intercommunication in olden time. It was Galileo who, using his new telescope, discovered that Jupiter had moons, and he made the happy suggestion that they might be used in the determination of longitudes. These moons revolve about Jupiter and are part of the time in the cone of shadow cast by Jupiter. The moment when, let us say, the first satellite plunges into the shadow, can be observed in two places whose difference in longitude it is desired to ascertain. As this satellite revolves about Jupiter once in less than two days, there are plenty of opportunities for observation. Moreover, tables can be computed, giving the times of disappearance as seen in Paris or Greenwich, so that an observer in America possessing such a table, can compute the difference in longitude on the spot. If one observes the time of immersion of the satellite at Philadelphia, then finds in his table the Greenwich time of immersion, the difference of the two times gives the time-difference in longitude between Philadelphia and Greenwich, which can be easily translated into degrees. Unfortunately, considerable errors arise, because the moment of apparent disappearance into the shadow depends

[7] Manuel Orozco y Berra, *op. cit.*, pp. 221, 222, 312.

upon the size of the telescope used. By order of the French Academy of Sciences, Father Louis Feullée, a learned Franciscan and pupil of the astronomer G. D. Cassini, made observations of longitude and latitude in various places in Europe and America. He visited the Antilles and Panama in 1703-05, the western coast of South America in 1707-1712. His physical, mathematical and botanical observations were published at Paris in 1725.

Eclipses of the sun and moon were observed in the heart of South America, in distant Paraguay, by a missionary, F. Bonaventura Suarez.[8] He observed a solar eclipse on November 5, 1706, "with a five-foot telescope and a pendulum vibrating seconds, with an equal motion, and rectified to true time by the altitude of the fixt stars." In 1728 "a tube of 10 foot" was used; in 1729 the motions of the satellites of Jupiter were watched with a tube of 13 foot; there was a conjunction of the first and second satellites, so that "both stars seemed to be one." In 1767 the Jesuits were driven out of Paraguay, and astronomical work ceased.

Longitudes were obtained also from lunar observations and lunar tables. In any case, the accurate determination of longitude and latitude calls for accurate instruments. It is not surprising that early determinations were extremely crude. Even after the clock and telescope were available gross errors arose. As an example, we cite a French observation near the mouth of the Mississippi. The French King sent the Jesuit Father Antoine J. Laval, a man of long experience in astronomical observation, to the Mississippi region to gather data for improved navigation and better maps. Though valuable in other respects, his maps showed wrong longitudes. On July 24, 1720, Laval observed the time of immersion of Jupiter's first satellite at Dauphine Isle, an island near the Alabama coast, which yielded as the longitude of that island 103° and some minutes west of Paris. Claude Delisle[9] criticized Laval's work, pointing out that 103° exceeded the previous estimate of Pitergos by 4°, of van Keulen by 6½°, of Delisle himself by 11°. If one considers that at the equator one degree means about 69½ miles, it is apparent that the location of Dauphine Isle was uncertain to the extent of many hundred miles. The same uncertainty affected the longitude of other points on the Gulf Coast. As a matter of fact, all of the above estimates were in excess; Dauphine Isle is about 90° 30′ west of Paris. Humboldt once said[10]

[8] Astronomical data were communicated in 1747 to the Royal Society of London. See *Philosophical Transactions*, Abridged, Vol. 10, Part I, London, 1756, pp. 118-124.

[9] *Mémoires de l'académie royale des sciences*, année 1726, pp. 249-258.

[10] *Voyage de Humboldt et Bonpland*, Troisiéme Partie, Paris, 1811, p. V, foot-note.

that as late as 1770 the latitude of Dresden was three minutes in error, that of Mannheim in 1790 about one minute and twenty-one seconds. Errors in longitude usually exceeded those of latitude. It was not till about 1790 that much greater precision in astronomical measurement became possible through the invention and manufacture of high-grade repeating circles by English and French mechanicians.

That the determination of longitudes and latitudes was persisted in is evident from the fact that in 1784 and 1785[11] there was published at Berlin a table of longitudes and latitudes of 200 important points on the earth and that a dozen places in Central and South America were mentioned; however, all longitudes differed widely from modern determinations. The satellites of Jupiter were observed later by Alexander von Humboldt in his travels in South America.

2. *Comets.* Comets were a subject of attention and solicitude in the New World, as well as the Old. As early as 1653, Gabriel Lopez de Bonilla, an astronomer and mathematician in the city of Mexico, published[12] a "Discourse" on the comet that appeared in December of 1653. The famous comet of 1680 which seemed to approach dangerously near to the sun, was observed and discussed in Europe and America. A German Jesuit, Valentin Stansel, who had taught rhetoric and mathematics at Olmütz and Prague, later became attached to the Jesuit College of San Salvador (Bahia) in Brazil, where he took astronomical observations, particularly on comets. These observations were sent to Europe and published in Latin in 1683 at Prague. Notices of this book appeared in the *Acta eruditorum* of Leipzig of 1683.

At the city of Mexico a discussion took place on the comet which touched theological as well as scientific considerations. A scholar of wide reputation in his day was Cárlos de Sigüenza y Góngora, interested in mathematical, philosophical and antiquarian subjects. He was born in the city of Mexico[13] in 1645, devoted himself assiduously to intellectual pursuits and became professor of cosmography and mathematics at the Royal University of Mexico. He was the first to prepare a general map of Mexico. He published at Mexico in 1681 a *Manifiesto* intended to reassure the people that comets were not tokens of the wrath of heaven. His liberal

[11] J. E. Bode: *Astronomisches Jahrbuch für das Jahr 1784, 1785*, Berlin.

[12] "Discurso y relacion cometographia del repentino aborto de los Astros, que sucedió del Cometa que apareció por Diziembre de 1653," noted in D. Vicente Riva Palacio's *México á Través de los Siglos*, Tomo II, Mexico, Barcelona [1888-89], pp. 738, 739.

[13] J. T. Medina: *La Imprenta en Mexico* (1539-1821), Tomo II, Santiago de Chile, 1907, pp. 415, 416.

opinions were opposed by Martin de la Torre, a Flemish nobleman who in a pamphlet[14] upheld the old and popular view that comets were signs of approaching disaster. Sigüenza replied with a tract[15] on "Mathematical Bellerophontes against astrological Chimeras." There was published in the same year, 1681, also a "Discourse cometological" by Joseph de Escodar Salmeron y Castro. This author was medical professor at the University. To this strange document which made the declaration that the comet was an exhalation of dead bodies and of human perspiration, Sigüenza made no reply. Most prominent and able among the critics of Sigüenza was the Jesuit, Eusebio Francisco Kino, who had just arrived from Spain and later became a pioneer missionary explorer in California. Born at Trent in Trentino, Kino had studied in Germany and distinguished himself at Freiburg and Ingolstadt in mathematics. He refused the offer of a professorship in the University of Ingolstadt, to become a missionary to heathen lands.[16] While waiting for a chance to cross the Atlantic, he took observations at Cadiz on the comet of 1680. When he arrived in Mexico he at once entered into the public discussion started by Sigüenza. Kino published at Mexico in 1681 a pamphlet under the title: "Astronomical Explanation of the Comet" presenting an able argument but using a tone not altogether free of arrogance. Sigüenza prepared a reply touching theologic and scientific questions. It was written in 1681 but did not appear in print until 1690. It was entitled *Libra astronómica y philosofica*, a title which Father Orazio Grassi had used in a reply to Galileo on the Comet of 1618. The prologue of the book was written by a hydrographer of high standing in Mexico, Don Sebastian de Guzman, a pupil of the learned mathematician, Ruesta. This prologue indicates some of the scientific questions that came under discussion, questions of parallax, of astronomical refraction, of whether the paths of comets were rectilinear as had been claimed by Kepler or a conic or helixes formed in accordance with Descartes' theory of vortices. Sigüenza challenged the reliability of Kino's observations, on the ground that the comet of the year 1680 could not be observed with accuracy in Europe because of its great declination and of its appearance in twilight.[17] Another publication on comets, from the pen of Gaspar Evelino[18] appeared at Mexico in 1682.

14 "Manifiesto Christiano en favor de los Cometas mantenidos en su natural significacion." See *México á Través de los Siglos*, Tomo II, p. 739.

15 "Belerofonte Mathematico contra la chimera astrologica." See Vol. II, p. 739, of *México á Través de los Siglos*.

16 H. E. Bolton: *Kino's Historical Memoir of Pimería Alta*, Vol. I. Cleveland, 1919, Introduction, p. 29.

17 Jose Mariano Berístain y Souza, *Biblioteca Hispano Americano Seten-*

We have dwelt at some length upon Sigüenza and his controversy on comets, because this debate is the earliest instance of a clash of intellects in public print on a scientific question that occurred in America. This controversy, conducted in a region far remote from the recognized centers of intellectual life, was very creditable and indicated that even distant America affords examples where in the seventeenth century the scientific method was arrayed in battle against the antiquated processes of theology and superstition.

3. *The earliest permanent observatory in America.* The city of Bogata in New Granada (the present Colombia) had the reputation of being "the Athens of South America;" it was the seat of scientific activity at the close of the eighteenth century. A Spanish scholar, José Celestino Mutis, assumed in 1762 the chair of Mathematics and Astronomy in the Colegio del Rosario, but the chief effort of his life in Bogota was botany. Noted is his study of Cinchona bark, the source of quinine. He was the first to teach the Copernican system in New Granada; he observed the hourly variations of the barometer. He took astronomical observations, but unfortunately never published them. He and Alexander von Humboldt were great friends. That his early interest in astronomy did not wane is evident from the fact that he founded an observatory in 1803[19] and became its first director. He trained many scientists, notably Francisco José de Caldas, who was in charge of the observatory for eight years after the death of Mutis in 1808, and then became a martyr in the cause of New Granada's independence from Spain. The claim that the astronomical observatory of Bogota is the earliest in America seems valid. We know that David Rittenhouse had an observatory at Norriton, near Philadelphia, for the observation of the transit of Venus in 1769, but that observatory was not permanent. The observatory at Bogota has not been in continuous use, nor did it contribute in any notable way to the progress of science. We are informed that in 1823 it was "absolutely abandoned,"[20] as was also the botanical garden at Bogota, but in later descriptions of Bogota the observatory is mentioned.

trional, 2 Ed., Tomo II, Amecameca, 1883, p. 127; Tomo III, p. 145. Several long quotations from the *Libra astronómica y philosofica* relating to longitudes, are found in Manuel Orozco y Berra's *Apuntes para la historia de la geografía*, 1881, p. 218-221.

[18] Manuel Orozco y Berra, *op. cit.*, p. 219.

[19] Carlos Navarro y Lamarca, *Compendio de la Historia general de América*, Buenos Aires, 1913, Tomo II, p. 303.

[20] Gaspard Théodore, Comte de Mollien, *Voyage dans la république de Colombia en 1823*, 2 Ed., Tome I, Paris, 1825, p. 282.

4. *Atmospheric refraction.* Ptolemy was the first to notice that light from a star undergoes a change in direction as it enters the earth's atmosphere, but no attempt was made to correct apparent positions of the celestial bodies before Tycho Brahe whose table of refractions was very imperfect. The law of refraction of light was first discovered by W. Snell in 1637. He showed that the sines of the angles of incidence and refraction bear a constant ratio to each other. The application of this to the atmosphere was far from easy. G. D. Cassini published tables in 1662 which corrected for the combined influence of parallax and refraction. But it became desirable to know the independent effects of these two elements. Jean Picard remarked in 1669 that probably refractions vary with the season of the year, and the different changes of the weather. Strangely Picard and Cassini thought they had reason to believe that refraction at the polar circle was double that at the parallel of Paris.[21] To explain the difference between these refractions of tropical regions and the temperate zone Bouguer set up the hypothesis that the nature of the atmosphere varied with the climate. Voyages were undertaken to determine altitudes above sea-level. Cayenne, the Cape of Good Hope, Quito, places in India were visited at different times by J. Richer, N. L. Lacaille, Bouguer and Legentil. The true explanation, to the effect that refraction is dependent upon atmospheric temperature and pressure, was advanced by Tobias Mayer and Lacaille, so that it is possible to construct tables of refraction which can be used in all climates and all parts of the world. Finally the observations made by Alexander von Humboldt during his travels in South America during the initial years of the nineteenth century helped to clear up this question. Our reference to Richer must be supplemented by the remarks that when in 1672 he was at Cayenne in Peru, he secured data on Mars for determining the parallax and he also made the notable observation that a pendulum adjusted at Paris to beat seconds lost at Cayenne two minutes daily. This observation bore on the then mooted question of the flattening of the earth.

5. *Meridian measurements for determining the shape and size of the earth.* Two meridian measurements were made in America during the eighteenth century, one in South America and one (by Mason and Dixon) in North America. Such projects require the greatest care and skill, as well as instruments of the highest degree of perfection obtainable. It is not surprising that both were carried out by men of European training. The earlier, which has been

[21] Voiron, *Histoire de l'Astronomie depuis 1781 jusqu'à 1811.* Paris, 1810, pp. 57, 58.

found the more valuable, was conducted in Peru, in the years 1735-1739, by Louis Godin, Pierre Bouguer and Charles-Marie De la Condamine, under the auspices of the French Royal Academy of Sciences, working in conjunction with two Spanish officers, Don George Juan and Don Antonio de Ulloa. While on their way, on the western coast of Ecuador, Bouguer and De la Condamine determined the position of the equator and chiseled upon the rocks an inscription to that effect. The plain north of Quito was chosen as best suited to base measurements; stations for triangulation were selected on the rugged mountains which hem in the valley in which Quito is situated. This Peru arc plays an important rôle in the early history of meridian measurements.

6. *The transit of Venus of 1769.* The transit of Venus over the disc of the sun in 1769 attracted a very great deal of attention in Europe, in the American colonies in North America, as well as in South America. In Philadelphia and Boston elaborate preparation were made for observing the event. In the city of Mexico it was observed by Father Josô Antonio Alzate, a most zealous student of the natural sciences in New Spain, who sent his observations to Paris, where they appeared in 1770.

A French expedition was made under the auspices of the French Academy of Sciences.[22] The observations were taken by Jean Chappe d'Auteroche at the Mission of San Joseph, located at the extreme southern terminus of Lower California, also by a Spanish actronomer.[23] Chappe's equipment comprised as the principal instruments a quadrant of three-foot radius, a transit instrument, an achromatic telescope of ten feet and another of three feet that were both constructed by Dollond in London, and a pendulum clock of Berthoud. On the morning of the eventful day, June 3, Chappe used in his preliminary observations only his left eye, saving his right eye for the important observations that came later. To his great joy, the observations were very successful. His position was one of the most favorable for data for the determination of the parallax of the sun. An epidemic was raging in the village; Chappe did all he could to alleviate suffering, but himself contracted the disease. Though ill, he successfully observed the eclipse of the moon on June 18, 1769. He died on August 1, a victim of the epidemic.

7. *Scientific periodicals.* The honor of having started scientific periodicals in the eighteenth century in New Spain belongs to Josô Antonio Alzate and Ignacio Bartolade. The latter started in

[22] *Philosophical Transactions*, Vol. 60, for the year 1770, London, 1771, p. 551.

[23] *Loc. cit.*, p. 549.

Mexico city the *Mercurio Volante* in 1772 which gave curious and important notices upon various matters in physics and medicine. It had an ephemeral existence. Alzate began in 1768 the *Diario literario de Mexico* which was soon suppressed, but it reappeared under a new title, to be again suppressed after eleven numbers had been issued, only to spring into existence a third time in 1787 under another name and going through fourteen issues. In 1788 the famous monthly, *Gaceta de Literatura de México* was started and it continued, though with some irregularity, until 1799, as a literary and scientific review. We have seen in it notices of experimental research conducted by Franklin, Lavoisier and others. Alzate himself took many astronomical and meteorological observations.

8. *Conclusion.* This rapid survey gives indication of early scientific activity worthy of systematic record. That much of it was the product of European talent is not surprising. That some of it represented the achievement of men born and educated in America is a source of satisfaction. The quality of work was mainly observational, consisting of the gathering of data on eclipses, transits, parallaxes, comets, meteorology, altitudes of celestial bodies, pendulum experiments, geodetic base measurement and atmospheric refraction. The applications of these data to scientific theory were made in the scientific centers of Europe where the data from different parts of the world could be gathered. Except for Sigüenza's general map of Mexico, the more important of the early maps were prepared in Europe by C. Delisle, G. B. Riccioli and others. The study of the shape and size of the earth and the preparation of tables of correction for astronomical refraction were made by astronomers in the old world. Nevertheless, even before the nineteenth century, America, though merely a distant outpost, was an integral part of the field of operations of the great army of scientific workers.

THE AGE OF THE EARTH[1]

By Professor JOHN JOLY, D.Sc. F.R.S.

"THE Age of the Earth" is a somewhat ambiguous phrase. From the geological point of view it is generally understood to mean the age of the ocean: in other words, the age of the earth since the beginning of those geological surface changes which are due to denudation. But another meaning may be ascribed to the term. We may assume the beginning to date from the cooling of a highly heated surface to the point of solidification. In this case we include in the age those long periods of Archæan time during which the activity of water played a subordinate part and volcanic commotion prevailed among the semi-fluid, rocky constituents of the globe. Yet a third interpretation refers the birth time to a still more remote and indefinite epoch when the world become differentiated as a planet by activities, of the nature of which we are ignorant. Astronomical deductions and speculations regarding the age are mainly concerned with the last period.

What I have to say will be restricted, almost entirely, to the first interpretation of the term. I mean by the age of the earth the period which has elapsed since its surface became the scene of world-wide denudative forces and the foundations of organic evolution were laid.

In virtue of these denudative forces we find ourselves possessed of certain methods of estimating the age which are valid upon the assumption that denudation proceeds in our time at a rate not greatly differing from its mean rate over geological time.

The bases of this assumption are as follows:

(*a*) That the chief factor in denudative activity being the rain supply falling on the land, solar heat and atmospheric circulation are primary causes. The life on the globe since very early times and the narrow temperature limits conditioning protoplasmic existence and activity show that great extremes of solar radiation can not have affected denudation for long periods in the past. Mere climatal extremes do not sensibly affect solvent denudation. Atmospheric circulation, being largely conditioned by the earth's rotation and the distribution of solar heat, can not have varied to any effective extent.

[1] Address before the Royal Institution of Great Britain.

(*b*) That a considerable percentage of the existing land area being rainless, changes in continental area can not greatly affect the amount of denudation: the belt undergoing denudation being merely displaced outwards or inwards. The evidence derived from paleography and from the extent of sedimentary deposits in all ages shows that the present land area is not greatly different from the past mean area.

(*c*) That the minor factors affecting solvent and detrital denudation being very many and of very different characters are unlikely to combine at any time, and for any long period, in one direction, so as to create a considerable departure from the mean.

Time will not permit a discussion of these statements. I shall refer but briefly to the methods by which the statistics of solvent and detrital denudation are used to afford the age of the ocean.

(1) The chemistry of the ocean and of the rocks is the key to our position. As the result of a comparative study of the primary or igneous rocks, and the secondary or sedimentary rocks, we find that, say, n grams of sodium are shed into the ocean for each ton of igneous rock converted into sedimentary rock, and in the ocean we find N grams of sodium. The total denudation over geological time has, therefore, been N/n expressed in tons of denuded igneous rock. Our study also tells us the average total loss attending the conversion of the primary rock into sediment, and so we get the total of the secondary rocks in tons. We now go to the principal rivers of the world, and availing ourselves of estimates which have been made of the amounts of sediment—*i. e.*, of secondary rock material—which they transport from the land in a year, we calculate the number of years it would take to lay down in the ocean the great mass of sediment generated in the past ages. After certain allowances this comes out at about 100 million years.

(2) Again the total of oceanic sodium may give us the age in another and more direct way. We know that by far the greater part of this sodium was carried into it by the rivers during geological time. We turn to the analyses of river water and estimate the total annual supply of this element to the ocean. Dividing the latter into the former and making certain allowances we find an age which is about 100 million years.

(3) A third and more difficult method is independent of our knowledge of chemical denudation. We estimate the maximum thickness of the integral sedimentary deposits, and knowing the burthen of sediment conveyed per annum by the rivers, we estimate the maximum thickness of deposit annually derived from the same; we divide the latter into the former and find an age which, again, is about 100 million years.

Of these methods, that which involves the sodium modulus only

is the most direct. Of course the reason for selecting this particular element as a modulus is because of its great solubility, on account of which it alone among the dissolved oceanic constituents has been preserved from organic abstraction or chemical precipitation. This method has been examined by many critics. Notably by Sollas, who, in a presidential address to the Geological Society in 1909, subjects it to searching examination. He concludes that a period of 175 millions of years may be reached upon certain assumptions, and that this must be very nearly the maximum allowable. My own examination of this method has led me to believe that it is *possible* that 150 millions of years may be indicated by it, and that 200 millions of years would not be reconcilable with our present knowledge of the factors involved. This would, as I have already stated, apply only to the duration of sedimentation. It can not be compared with data which apply to an age dating back into the Archæan.

There was, indeed, some scanty sedimentation in Archæan times. We can not form any estimate of its effects upon our numerator or upon our denominator save that we seem entitled to conclude that they were small. "The Archæan was essentially a period of world-wide vulcanism, and in the relative proportion of rocks of igneous and sedimentary origin represents a departure from the uniformity of conditions of later geological time." I quote from the monograph of Vane Hise and Leith.

Before passing on to the results based upon radio-activity I must refer to one point in particular which has been urged against accepting present-day rates of denudation as a basis of time measurement. It is said we live in a period of abnormal continental elevation which, it is asserted, involves excessive solvent denudation. A little attention to the nature and conditions of solvent denudation should have sufficed to forestall the argument. But a ready method of dealing with it is available. The continent of North America has a mean elevation of 700 metres: it is being denuded at the rate of 79 tons per square mile per annum; for South America the corresponding figures are 650 metres and 50 tons. Now Europe has a much lower mean elevation—300 metres. Its rate of denudation is, however, 100 tons per square mile per annum. The rate of solvent denudation is, in fact, by measurement found to be *less* for the more elevated land, as theoretically it should be. The argument then, if it has any basis, would indicate that the age as found from solvent denudation is excessive.

Prior to the advent of those methods for investigating the earth's age, which are based on radio-active changes in the elements, no serious objections to the results reached by the geological methods were raised, so far as I know. There were some, indeed,

who regarded the age as excessive. Thus Becker arrived at a lesser figure by taking into account the progressive impoverishment of the surface materials during geological time. The validity of the correction is, however, open to doubt. Others considered that the organic changes recorded in the rocks required a longer period. Sollas gave, as I think, a clear answer to this objection in his "Age of the Earth." Both Lyell and Geikie, and Poulton, had in past years upheld the doctrine of Uniformity. But the advent of the radio-active method, as founded on the uranium family of elements, seemed to point to a vastly greater age; leading, in fact, to the extraordinary conclusion that the present rate of solvent denudation is not less than four times, and may be eight (or even more) times, in excess of the average rate obtaining during the past.

The earliest suggestion of the possibility of using the stored-up products of radio-active change came from Rutherford. He, and later Strutt (now Lord Rayleigh), applied the accumulation of helium to the evaluation of geological time. Strutt laid out a geological chronology, the first of its kind, but considered he was dealing with minor limits. Boltwood used the residual product of uranium—lead—and for Archæan (?) materials reached as much as 1640 million years. As I have already said, the denudative method can not be regarded as extending to those remote times. But such results as 480×10^6 years for Silurian or Ordovician deposits, and 1200×10^6 years for Post-Jatulian, are quite out of harmony with the denudative method. To-day the matter stands thus: A number of results are available based upon the use of carefully selected material, and when the material is thus selected the ratio of lead to uranium—the "lead ratio" as it is termed—increases as we go downwards and diminishes as we go upwards in the strata, preserving a fair degree of agreement even for widely separated localities.

Those who would rest content with this result, however, can do so only by ignoring the very interesting and suggestive fact that when we base the results on the lead ratio of selected thorium minerals, we arrive at ages which are in substantial agreement with the results reached by the denudative method. On the face of it this agreement gives strong support to the conclusions reached by methods absolutely different in nature.

For long it was known that thorium minerals—such as thorite—gave persistently lower ages than uranium minerals. It became the custom with some to treat these ages as untrustworthy. But we know now that this attitude is not justified, but rather that the onus of explaining away the impressive agreement between the indications of thorium lead and denudative statistics rests with those who would reject the age supported by both.

Soddy's determination of the atomic weight of the thorium lead isotope in 1917 afforded material for an age determination on a very large scale, and from the nature of the research, one of special value. The material was a thorite from Ceylon; from rocks immediately overlying the Charnockite series. The latter is extremely ancient—Lewisian or Lower Archæan. Upon reading in *Nature* Professor Soddy's account of his determination of the atomic weight of the lead derived from these rocks, I estimated that the quantity of lead extracted from the thorite gave an age of 130 millions of years for the time since this mineral had been generated; and on communicating with Professor Soddy I found that he had reached a somewhat similar conclusion.

At this time, however, there was the possibility that thorium lead was not altogether stable. Suspicion fell more especially on thallium as the final product. Two experimental results, however, laid this doubt to rest; experiments upon a thorianite made in my laboratory by J. R. Cotter failed to detect even spectroscopic traces of this element, and there was insufficient thallium found in the thorite dealt with by Professor Soddy. In a subsequent letter to *Nature* Professor Soddy states that a research carried out at the Radium Institute of Vienna supported the view that the lead isotopes derived from thorium were both stable. I shall refer presently to yet additional evidence that the transformations of the thorium family cease with lead.

Writing to *Nature* in support of the hypothesis then under discussion—*i. e.*, that thorium lead was unstable—A. Holmes cited a result on a selected specimen of uraninite, showing that the rocks in which Soddy's thorite occurred were, according to the uranium-lead ratio, 512 millions of years old. Previous uranium-lead ratios had assigned a much greater age to them. Here, then, the results join issue: the uranium result is just four times as great as the thorium. We notice, too, that on the uranium-scale of time this thorite must be older than Silurian or Ordovician, which have been determined by uranium lead as 430 millions of years ago. Probably its age dates back to Cambrian or even to pre-Cambrian time. From what we have already inferred we can not regard 130 millions of years for early Palæozoic times as irreconcilable with the maxima which denudative methods afford. More recently, lead derived from a Norwegian thorite of Langesundfiord—also of lower Palæozoic age—seems to reveal an age of 150 millions of years. In this case, also, there is the added security of a determination of the atomic weight of the lead.

We can not discredit these results on the score of radio-active instability of the lead. Why, then, set them aside in favor of results reached on uranium lead, which are in hopeless contradiction

to the indications of the record of the surface activities of the globe? It is, indeed, not too much to say that the whole position is now reversed, and that to-day suspicion attaches to the uranium-lead ratio. And, as we shall see, there is much unknown about the earlier radio-active sequence in the uranium series, while the discovery of isotopes opens the way to possibilities unthought of in the earlier days of radio-active science.

I shall, however, now turn to the evidence of the pleochroic halo on this matter.

The halo affords a means of investigating certain facts respecting the break-up of the radio-active elements in the remote past. For the dimensions of the halo—minute though they be—can be determined with considerable accuracy, and these dimensions are conditioned by the added effects of the several α-rays emitted by the transmuting elements. Bragg and Kleeman observed and measured just such integral ionization effects in air. In the rocks the ionization curves, owing to the great stopping power of minerals, are on a scale 2,000 times as small. They are very faithful hieroglyphics, however, and carry back our knowledge over an appalling vista of time.

One single α-ray produces a well-known curve of ionization determined by Geiger. The range of the rays does not affect the general nature of the curve. If we imagine uranium or thorium as parent elements contained in a minute crystal—of zircon, for instance—we must picture the various α-rays affecting the surrounding substance—mica, we may suppose—in such a way as to build up concentric spherical shells more or less overlapping and corresponding to the radial distances at which the ionization of the several rays is at a maximum. As seen in section upon cleaved flakes of the mica, we find concentric colored rings representing the ionization due to the rays.

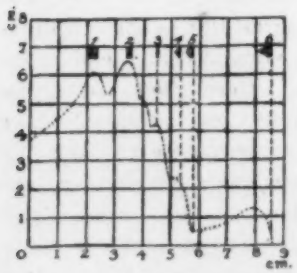


FIG. 1

In order to arrive at the theoretical location of these rings we must add up the several ionization effects as observed in air. This involves assigning a Geiger curve to each ray according to its range and adding up the ordinates.

Let us consider first the case of the thorium halo. Fig. 1 is a curve arrived at in the manner I have just described. Its ordinates are proportional to the integral ionization effects of those radio-active elements in the thorium series which emit α-rays. And above it I have marked, calculated into the range in air, the positions of

the colored rings which in biotite we observe encircling a minute mineral particle containing thorium and all the successive products of its transmutation. This, of course, necessitates magnifying the halo enormously—rather more than 2,000 diameters. You perceive that the halo very faithfully conforms to the features of the air-curve. It may be of interest to mention that the finding of the third ring led to the discovery of the prominence on the curve which accounts for it. This part of the curve had originally been plotted from an insufficient number of ordinates. This close agreement really reveals a very important fact. The air-curve depends for its dimensions on the ranges of the several α-rays as we measure them to-day in the laboratory. The halo-measurements refer to radio-active effects which began their record in this mica in Carboniferous times—possibly long before. The halo reveals no sign of change in the several ranges concerned. As you are aware, the rate of break up, the transformation constant of the element, is related to the range. We are, therefore, in the case of the thorium family, entitled to read in these minute and ancient records a guarantee that the accumulation of the final product—the thorium isotopes of lead—was in the remote past affected at just such a rate as we have inferred from the splendid researches of our day. The thorium halo gives us this guarantee. It also tells us that it is improbable that the resulting lead is unstable. For if it were we must find room for rays additional to those we have used in deriving the ionization curve. True, a coincidence of range might enable a ray to lie concealed in the halo; but the fit of the halo is so absolutely faithful to every feature of the curve that this seems improbable.

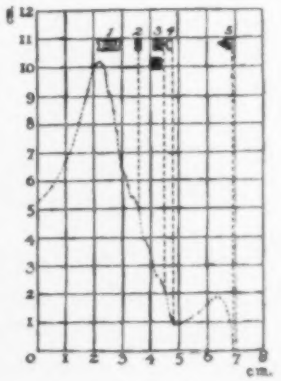


FIG. 2

It is also possible to observe the successive stages of development in thorium haloes. The first rings to appear are those corresponding to the two conspicuous crests of the curve, Fig. 1. If the central nucleus is small or feeble, nothing more may be developed.

We now turn to the uranium curve. The eight contributory ionization curves are placed according to the range of each ray, and Fig. 2 shows the curve produced by adding up the ordinates. Above it are laid out the several rings observed in the uranium halo. Looking at these rings, we notice that the outer features of the halo seem in fair agreement with the present-day ranges. But the innermost ring has a larger radius than would

be expected from the curve. Much care has been expended in verifying this point. In the Devonian mica of County Carlow these haloes are found in every stage of development according to the size or activity of the nucleus. The uranium halo begins as a single delicate ring surrounding the minute central nucleus. It can be measured from a stage bordering on invisibility to a stage when its central area is beginning to darken up and the first shadowy signs of the outermost ring of all—that due solely to radium C—appear. A large number of readings on these embryonic haloes, made recently by various observers, confirm the mean value of its radius as cited in a paper communicated to the Royal Society in 1916. The discrepancy with the theoretic curve is small: 10 or 12 per cent. of the external radius. The allowance for, and measurement of, the nucleus is sufficiently difficult to introduce some uncertainty.

This misfit may be of considerable significance. I have already reminded you that the range of the *a*-ray emitted by a transforming element is related to its rate of break-up. The range is longer for the shorter-lived elements. Now, here the first ring of the uranium halo in mica shows a longer range than we would expect from the air-curve as observed to-day. The agreement between the two in other cases appears to show that this is not due to any unknown effect influencing the retardation in mica. The location of the first uranium ring is mainly referable to those short-range *a*-rays arising from the initial transformations of the uranium series. We infer that one or more of these rays must have had a longer range in past times, and, of course, that the corresponding transformation periods must have been shorter. A specially influential ray is that slowest of all the rays—that which is emitted in the break-up of uranium 1. The discrepancy might be due to this ray possessing a greater range in early geological times. But, whatever the cause, the nature of the misfit suggests evidently that formerly the rate of transformation of uranium to lead was faster than it is to-day.

It is with some reserve that I refer here to measurements made lately on haloes of comparatively recent and of very remote geological ages. I say "with reserve," for not only are the results of a nature calling for very adequate confirmation, but the measurements present considerable difficulty. The point at issue may be stated in a few words: Is the abnormality observed in the dimensions of the uranium halo dependent in amount upon the antiquity of the rock in which the halo is developed?

I had sought occasionally for uranium haloes in rocks younger than the Leinster granite—which is of early Devonian age. The granite of Mourne, which is of Eocene or early Tertiary age, for

long refused to reveal any haloes suitable for measurement. However, recently I was so fortunate as to find a few of these early halo rings which I was able to measure. Further search has revealed a few more; but they are excessively scarce and rather difficult to detect. The nuclei of these haloes are only rarely zircon—they seem to be apatite; possibly allanite—and their average size is greater than the zircon nuclei of the Carlow mica. Both the mineral nature of the Mourne nuclei and their dimensions involve, therefore, a bigger subtractive correction on the observed radius than is required in the case of the Carlow haloes. But in addition to this, there appears to be a small difference in the external radius of the Eocene halo and that of the Devonian halo. According to a large number of readings by several observers, some of whom were not acquainted with the question at issue, the external radius of the Eocene halo-ring—no allowance being made for the nuclear radius—is 0·0135 mm. The same observers obtained for the Devonian halo 0·0146 mm.—without allowance for the nucleus. The nuclear correction, as I have said, would have increased the discrepancy, but the correction is a difficult one. There is no reason to believe that *more* than 1 per cent. of this difference can be ascribed to the chemical composition or density of the micas, both of which have been investigated.

Still more recently I have found these primary ring-haloes in the micas of Arendal and Yitterby, which are said to be of Archæan age, and which are certainly extremely ancient. These haloes appear to possess a radial dimension of 0·0160 mm., or a little less. Here, again, the nature of the mica does not appear to be responsible. According to these measurements it would appear that the radius of the Eocene halo-ring must be increased by about 7 per cent. to attain the size of the Devonian halo-ring, and that this is, in radial dimension about 10 per cent. smaller than the Archæan. It would seem as if we might determine a geological chronology on the dimension of these halo rings!

The foregoing results, if confirmed, would give strong support to the view that some factor, variable over geological time, had affected the ranges and periods of certain elements concerned in building up the uranium halo. However, too much stress must not be placed on these measurements till they are confirmed by haloes in yet other micas. Pending further investigations, I return to the fact that the uranium halo of Devonian age does not conform to the ionization curve of the uranium family as determined on present-day measurements. Serious discrepancy seems confined to the shorter ranges, more especially with that primary range which is most influential in determining the rate of production of uranium lead.

We do not appear to be in a position to deny the possibility that uranium 1 may have slowed down in its rate of decay over geological time. Such laboratory observations as can be extended to the case of short-lived elements would not, probably, shed any light on the matter. It is a possibility long ago suggested by Rutherford. But if this is the explanation we must admit that in the case of thorium any corresponding effect must have been much smaller. On the whole the former influence of one or more isotopes of uranium—which possibly may almost have disappeared—seems the more probable explanation. Hypothetical isotopes of uranium have been invoked by highly competent authorities to meet the difficulties affecting the ionization accounts of the uranium family of elements. Boltwood suggests as "not impossible" that what we now call uranium consists of three radio-elements: a parent element and two isotopic products all emitting *a*-rays.[2] In 1917 A. Piccard put forward the view that the parent of actinium is a third isotope of uranium not belonging to the uranium family and having an atomic weight of 240. This view is regarded favorably by Soddy and Cranston. It clears up the difficulty respecting the atomic weight of uranium, and fits in with the atomic weights of radium and of uranium lead. Soddy and Cranston remark that in order to explain, in this case, the constant ratio of actinium to uranium observed in minerals we must suppose the period of uranium 1 and of the hypothetical isotope to be the same. This difficulty, however, is removed if we may assume that the ratio varied over geological time.

A somewhat similar theory to Piccard's may be invoked to explain the abnormality of the Devonian uranium halo. We have these facts to go on: The age indicated by uranium for Lower or Pre-Palæozoic rocks is about four times too great as compared with the age indicated by thorium. We assume, therefore, that three fourths of the lead as measured in uranium minerals is derived from a certain isotope. This isotope, not having been detected in our time by its primary *a*-radiation, we must suppose to be now sensibly exhausted. We, therefore, have a known mass of this isotope transforming to lead in a known time —130×10^6 years. Assuming that only 1 per cent. of it is left we get its transformation constant ($3{\cdot}5 \times 10^{-8}$), and by Geiger and Nutall's relation we find the corresponding range as 2·6 cms. at 0° C.; or about 2·75 cms. at 15° C. To-day the *a*-radiation of the hypothetical body would be only $\frac{1}{1000}$ of that due to uranium 1, but during the period since the Devonian there will be about three *a*-rays from the short-lived isotope to one from the long-lived. The integral curve of ionization

[2] *Phil. Mag.*, 6 S., Vol. XL, p. 50, 1920.

as modified by these hypothetical results would be in agreement with the Devonian halo. We have to assume that the ranges of the rays emitted by the successive disintegrating products of the supposed isotope were such as to leave the outer features of the halo sensibly undisturbed. This seems not improbable.

The salient features which appear in the study of radio-active haloes are: Firstly, that the agreement of our laboratory measurements of to-day with the features of the Palæozoic thorium halo is such as to support the view that the periods of the several elements concerned in its genesis have remained unchanged over 130 millions of years. This fact, taken along with the stability of thorium lead, seems to render its reading of geological time authentic in a high degree. Its indications are confirmed by the consistent testimony of the denudative processes which have progressed on the earth's surface. Secondly, it appears that the uranium halo is not in conformity with the period we ascribe to-day to uranium—a disagreement which is emphasized by the failure of uranium-time to conform with the united testimony of thorium-time and denudative-time; as well as by much that remains unexplained respecting the earlier changes in the uranium family elements.

The complete tale is not yet told, but I think the balance of probability is in favor of an age between 150 and 200 millions of years for the earliest advent of geological conditions upon the globe.

Astronomical investigation on the subject of the age of the earth deals, generally, with that greater age which must be ascribed to the earth as a planet. For this age vast periods have been claimed. But it is possible to reconcile superior ages for the earth as a planet with comparatively brief geological time. And, to my mind, in doing so we proceed upon what is no more than a necessary deduction based on our knowledge of the radio-activity of terrestrial materials. I would go further—still, as I believe, logically—and ascribe to radio-active energy an influence on planetary and stellar evolution much greater than has hitherto been admitted.

The only planet we can investigate at all closely is, of course, our earth. And what do we find? In its surface materials there are sufficient of the radio-active elements, as Lord Rayleigh first showed, to account for the observed average temperature gradient if the surface conditions extend a little way, about 19 kilometers, inwards. It is, for many reasons, in the highest degree improbable that such a definitely defined radio-active layer exists. Nor is it probable that the earth's interior is free from radio-active substances. We find both uranium and thorium in meteorites containing a large percentage of iron and nickel, and, although they have

not as yet been found in meteoric iron, we know from the mean density of the earth that its interior can not be composed of pure iron. It is probable that a considerable proportion (some 40 per cent.) of silicious materials are intermingled; and when such exists in meteorites invariably we find the radio-active elements. By what conceivable activity was all the uranium and thorium separated out and brought to the surface?

The view that radio-active elements exist in the earth's interior is sometimes met by a formal denial that the earth can be getting hotter within. Upon what evidence is this denial based? If the central core of the earth for a radial distance of 2,000 kilometres, say, had risen in temperature by 1,000° C. over geological time—and upon a low assumption of the interior radio-activity it might reach this temperature in 150 million years—would we be aware of the fact? Would the day be appreciably lengthened? Would there be any effect at all if the outer parts were cooling due to loss of primal heat? We have further to consider that only over the short period of historical time would any observations be available. The denial is quite baseless so far as my estimates go.

Well, then, if our earth is heating up within, is there not an impending termination to our geological age? Kelvin showed how complete is the thermal isolation of the earth's interior, and it is certain that interior heat is not now escaping. The rise of temperature within must go on till the present epoch succumbs to the accumulated energy. Then must ensue a period of vulcanicity which will end life upon the globe, and probably reverse the chemical work stored up by ages of denudative and organic activity. The whole sequence of events—rapid cooling by radiation, restoration of the oceans, and, possibly, re-birth of life and of its evolutionary history—would begin all over again. On this view the age we have been studying may be one of many, and will inevitably attain its three score and ten, terminating in labor and sorrow. But there must come a rejuvenation, and the rejuvenation, possibly, may one day be pondered by other minds than ours. Remember that after some ten thousand millions of years there still survives 50 per cent. of the heat-generating elements, and the effect of their diminution is only to lengthen out the recurring geological ages. Our planetary companions may be in various stages of such cyclical changes.

THE PROGRESS OF SCIENCE

CURRENT COMMENT

AN INVENTORY OF ENERGY

By Dr. Edwin E. Slosson,

Science Service, Washington.

Our modern civilization has been developed by the lavish expenditure of the potential energy accumulated in the form of fossil fuel during geologic ages. Our wealth and industries, our comforts and luxuries, our science and art, our power and population, all are dependent upon the continuance of an adequate supply of energy from some source.

But the sources on which we are now relying, coal, oil and gas, are being rapidly used up and are irreplaceable. Natural gas is almost exhausted. Gasoline production is about at its peak. Of coal the United States has enough for five thousand years, but many countries have not any.

It is high time the world took stock of all conceivable sources of mechanical power to determine how far civilization may be developed or how long it may be maintained at the present level. Such an inventory would require the cooperation of the scientists and engineers of all nations in an investigation lasting many years. But fortunately the means of such cooperation now exist for the first time in the International Research Council which at its last meeting in Brussels last July took under consideration this project. The question was also discussed at the Boston meeting of the American Association for the Advancement of Science the last week of the year.

Popular confidence that "science will find a way" before there is any serious shortage is flattering—but unfounded. If we try to list all the sources of energy that we can think of we shall find that none of them is yet available or certain ever to be secured in adequate quantity.

Our primary and only practical source of energy is the sun. The sunshine falling upon a square mile of land at sea-level in our latitude in the course of a year is equivalent on the average to 700,000 horse-power. To give us each the amount of energy we are now employing, one and a half horse-power, 60 square feet would be sufficient.

But no satisfactory solar engine has yet been discovered, so we are not able to make use of this abundant supply directly. Indirectly we can employ it in various ways. The heat of the sun causes currents in the air which we can use to propel sailboats and run windmills. Doubtless wind-power can and will be used more in the future for both purposes, but the winds are variable and insufficient. The same may be said of the waves and of the rise and fall of the tides caused by the attraction of the sun and moon. Something may be done with them, but we must not expect too much.

The power that the sun provides continuously by pumping up water from the sea and depositing it upon the mountains in the form of rain can be used by damming up the streams and interposing turbines. We should make use of such water-power as rapidly and completely as possible to save our fossil fuel, but there is not enough of it in all the world to replace the coal consumed and even in our favored land we could barely get enough power by harnessing all the falling streams to satisfy our present population, to say nothing of future needs.

DR. CHARLES D. WALCOTT

Secretary of the Smithsonian Institution, president of the National Academy of Scien formerly director of the U. S. Geological Survey, elected at the Boston meeting president the American Association for the Advancement of Science.

Some day the world will have to stop drawing upon its carboniferous banks and live within its income. It will have to grow its fuel year by year as it grows its food. But it would be a great shock to civilization to have to shift back from coal and oil to the wood of two hundred years ago.

When we turn from the sun to the earth, we find here also an abundance of power but no way to get it. We are living on top of a furnace, but fortunately for us the lid is thick and non-conducting. It has been often suggested that a hole might be bored down through the crust of the earth into the heated interior a few miles below and through this water might be poured down to come up steam. But this remains an engineering dream.

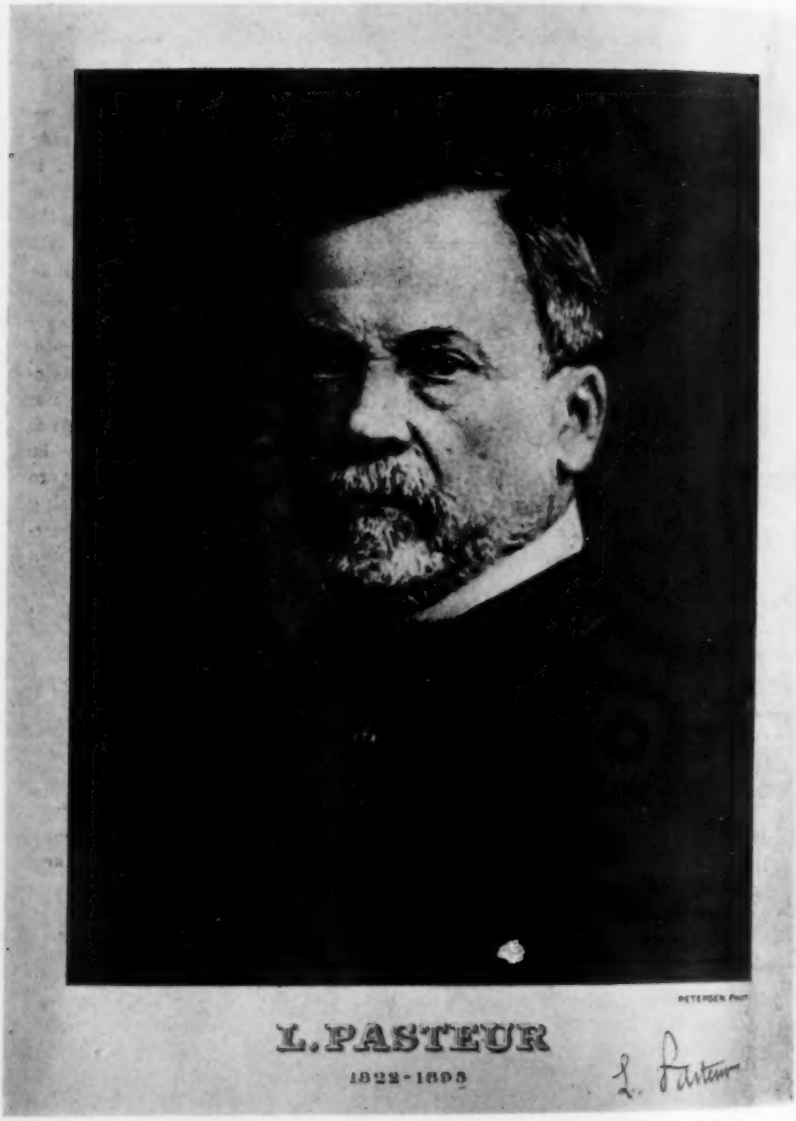
Last and most illusive of all is the internal energy of the atom, revealed to us in the heat that radium is continually giving off. We are using radium rays already to illuminate watch dials and scorch out cancer, but all the elements have similar stores of energy if we only knew how to release it. What it would mean if we should gain access to this exhaustless supply of potential wealth H. G. Wells has tried to tell in his romance, "The World Set Free," but even his brilliant imagination is baffled by its dazzling possibilities. But so far scientists have not been able to unlock the atomic energy except by the employment of greater energy from another source.

Such in brief is our present situation and future prospects. The lesson of it is, first, that we should curtail the waste of our coal and oil, a loss to our country of a billion dollars a year, and, second, that we should start systematic research to develop new means of obtaining power, such as a machine for converting the sunshine into electrical current.

ELECTRICITY FROM SPUTTER WORK

POWER, more power, is the cry of the age. With a coal shortage upon us in midwinter and with a permanent petroleum famine impending, the eyes of the thoughtful are turned toward the development of new sources of heat and mechanical energy. There are two sources known that would satisfy all our wants if we could make efficient use of them. One is the heat of the sun and the other is the internal energy of the atom. The sun's heat we do use indirectly by the combustion of wood and coal. But the plant is a shockingly inefficient solar machine. No up-to-date factory would use such a wasteful machine, although we should not complain of it so long as we can not beat it. But some day we may be able to transform heat directly to electric current without going through the roundabout way of growing plant and steam engine and dynamo.

A new way of generating electricity directly from heat was pointed out by Dr. R. M. Holmes, of Cornell University, before the American Association for the Advancement of Science at the Boston meeting in Christmas week. His apparatus might be called "the sputter transformer," since it uses a film made by what physicists call "sputtering," that is, the driving off of extremely minute particles of a metal by electricity in a gas of low pressure and catching them on a glass plate. A film so made contains some atoms of gas entangled in the metal. Anyhow it acts like a different metal. Now it has long been known that when two wires of different metals are soldered together in a ring and one junction heated while the other is cooled an electric current will start up and flow around the circuit. When the two wires are of the same metal no current is produced. Now Dr.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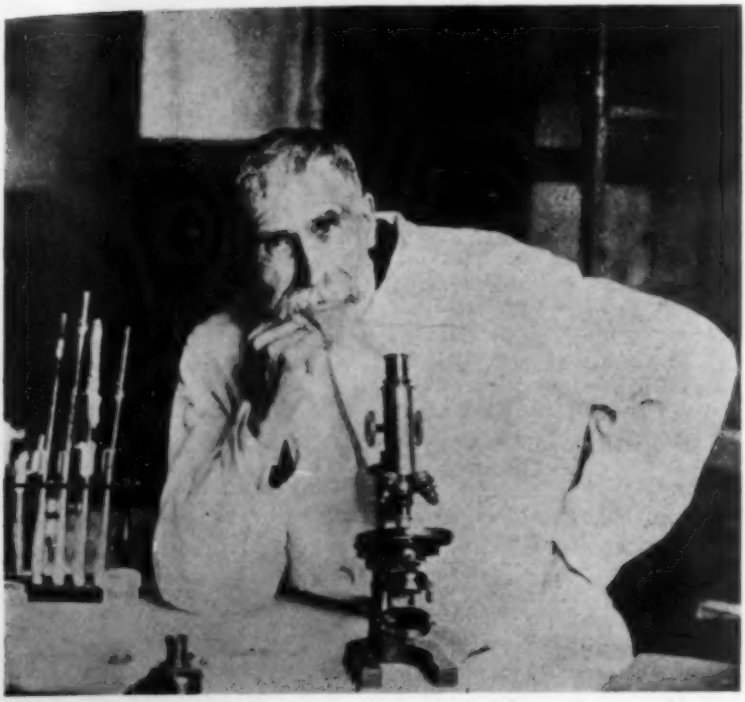

DR. EMILE ROUX

Since 1878 associated with Pasteur in his work, since 1904 director of the Pasteur Institute in Paris.

Holmes finds that his sputtered film, when connected up with an ordinary piece of the same metal, will produce a current when the two junctions are heated unequally. To see if the absorbed gas was the cause of the difference in the sputtered metal, he tried the metal palladium which has the remarkable ability of absorbing a thousand times its own volume of hydrogen gas. The gas-filled palladium connected up with the ordinary gas-free palladium was found to work in the same way, that is, a current passed from the former to the latter at the cold junction.

Where did the current come from? According to modern theory an electrical current is a stream of loose electrons, that is, of atoms of negative electricity. All metals are supposed to contain such electrons wandering about freely like the particles of air in a room. But different metals have different numbers of them in the same sized piece of metal, and when a metal densely filled with them is brought into contact with a metal wherein they are comparatively scarce, they pass over into the emptier room. If this junction is kept cold and the other junction is heated the current is continuous. Dr. Holmes suggests that in his gas-filled metals the gas molecules may have crowded the electrons into smaller space and so increased their pressure, or else that the extra electrons may come from the hydrogen atoms.

To avoid raising false hopes Dr. Holmes adds that "there seems to be no possibility of applying the method for the generation of electricity upon a commercial basis because of the smallness of the effects produced and because of certain losses which seem

CONFERRING OF THE NOBEL PRIZES AT STOCKHOLM

The directors of the Nobel Institute and winners of the Nobel prizes (each of which is of the value of $40,000). Those to whom prizes were awarded and who were able to go to Stockholm are in the front row. From left to right they are: Professor Niels Bohr, of Copenhagen, who received the prize in physics for 1922; Professor Francis William Aston, of Cambridge University, who received the prize in chemistry for 1922, and Professor Frederick Soddy, of Oxford University, who received the prize in chemistry for 1921. Professor Albert Einstein, who received the prize in physics, was unable to be present owing to the eclipse expedition to the South Pacific.

inevitable with any arrangement for this direct transformation of heat into electrical energy.'' So if the reader is approached by an agent with an agate-bearing tongue to take stock in a sputter engine he should investigate before investing. Still it is interesting to know of a new way of solving this vital problem, even if it does not seem of practical value. Here is a most enticing field of research for it offers both fame and fortune. An efficient transformer of the radiant energy of the sun into mechanical work would put a power plant in any vacant lot and make a desert as valuable as a coal field.

EARLY RISERS

THE youngest man to receive a Nobel award is Dr. Niels Bohr, of Copenhagen, who this month is awarded the prize for the greatest discovery in physics. He is only thirty-seven now and he was only twenty-eight when he startled the world by his bold conception of the atom as a sort of solar system in which the sun is represented by a nucleus of positive electricity and the planets by particles of negative electricity revolving around it with amazing speed. On this theory he was able to calculate just what shiftings in the orbits of these planetary electrons would give off light of the particular wave-length to make each line of the spectrum.

But it was a man even younger who in the same eventful year, 1913, made a still greater contribution to our knowledge of the interior of the atom. Henry Moseley, the Englishman, was only twenty-six when he found a way to analyze the elements by the reflection of X-rays from their atoms. This led him to ''the most important generalization in the history of chemistry since Mendeléff's Periodic Law,'' the idea that the chemical properties of an element depend upon the number of free charges of positive electricity upon its nucleus. This shows us that there are ninety-two possible elements between hydrogen, the lightest, and uranium, the heaviest, and they are now all known but four.

Two years later young Moseley was killed at Gallipoli and the premature extinction of his brilliant brain was one of the greatest losses of the great war, a loss that no territorial gains can compensate, and it was, as we now know, a useless sacrifice, for Gallipoli has gone back to the Turks. ''Some one had blundered.''

In the history of science we often observe that epoch-making ideas have sprung from the brains of young men. Svante Arrhenius, the Swede, was only twenty-four when he devised the electrolytic theory of solution, the idea that salts are decomposed in water to positive and negative parts. Kekulé, the German, was twenty-eight when he hit upon the theory of types, which led him, at the age of thirty-six, to the symbol of the benzene ring. Berthelot, the Frenchman, was only twenty-four when he began his career in what he called ''creative chemistry'' by the synthesis of benzene compounds. William Crookes, the Englishman, was twenty-nine when he discovered thallium by the spectroscope, a new metal by a new method. Emil Fischer, the German, was twenty-three when he discovered the hydrazine reaction that led to the analysis and synthesis of the sugars. Perkin, the Englishman, was eighteen when he discovered the first aniline dye, mauve. Pasteur, the Frenchman, was twenty when he became intrigued with the puzzle of the right and left-handed crystals of tartaric acid which six years later he solved by making the inactive racemic acid by combining the two forms.

Twenty years later the explanation of this phenomenon burst simultaneously in the brains of two young men, the Frenchman, Le Bel, and the Dutchman, Van't Hoff. The former

was twenty-seven and the latter was twenty-two. Van't Hoff was still a student when he published his eleven-page pamphlet on "The Structure of the Atoms in Space," and how he did get laughed at by his elders for his crazy notion.

Albert Einstein conceived the idea of his theory of relativity when he was eighteen and published it at twenty-six. He is, as we should expect, an advocate of shortening up the school period and making it more practical, so that the student can get at his life work earlier. This at least seems the best plan for brilliant minds like these and educators are coming to the conclusion that special facilities should be afforded such so they can advance as fast as they can without waiting on their slower schoolmates. To give one young man of this sort the peculiar training he needs will benefit the world more than the education of a whole collegeful of the ordinary caliber.

O. W. Holmes used to say of infant prodigies that those who get up so early in the morning are apt to be very conceited all the forenoon and very sleepy all the afternoon. But this does not seem to apply to the cases we have here considered.

SCIENTIFIC ITEMS

DR. CHARLES D. WALCOTT, secretary of the Smithsonian Institution and president of the National Academy of Sciences, formerly director of the United States Geological Survey, has been elected president of the American Association for the Advancement of Science.

DR. W. W. CAMPBELL, director of the Lick Observatory, Mount Hamilton, California, on January 4 was unanimously named president of the University of California by the regents, succeeding Dr. Davis Prescott Barrows. Dr. Campbell remains director of the Lick Observatory. He will take office on July 1, when Dr. Barrows will become professor of political science.

DR. SAMUEL WESLEY STRATTON, director since its establishment in 1901 of the Bureau of Standards, now president of the Massachusetts Institute of Technology, was the guest of honor at a farewell reception at the bureau on December 14.

DR. ROBERT A. MILLIKAN, of the California Institute of Technology, Pasadena, has been awarded the 1922 Edison medal of the American Institute of Electrical Engineers, for "meritorious experimental achievement in electrical science."

DR. HANS ZINSSER, since 1913 professor of bacteriology at Columbia University and bacteriologist of the Presbyterian Hospital, has been elected as professor of bacteriology and immunology in the Harvard Medical School.

THE Rockefeller Foundation and the General Education Board have each given $1,250,000 to the College of Medicine of the State University of Iowa. The legislature will be asked to appropriate $2,500,000 at the rate of $450,000 a year for the building and equipment of hospitals and laboratories.

PRINCETON UNIVERSITY has received a gift of $100,000 from Henry Lane Eno, research associate in psychology, and $25,000 from an unnamed alumnus, for the construction of a psychological laboratory.